Kagisano

Number: 13

The Fourth Industrial Revolution and Higher Education in South Africa

May 2022

CHE

COUNCIL ON HIGHER EDUCATION

COUNCIL ON HIGHER EDUCATION

Kagisano
Number: 13

The Fourth Industrial Revolution and Higher Education in South Africa

May 2022

Published by the Council on Higher Education (CHE)

The CHE is an independent statutory body established in terms of the provisions of the Higher Education Act No. 101 of 1997, as amended. It advises the Minister responsible for higher education and training, and is the national authority for external quality assurance and promotion in higher education. In terms of the National Qualifications Framework Act No. 67 of 2008, as amended, the CHE is the Quality Council for higher education responsible for, among others, the development, further development and management of the Higher Education Qualifications Sub-Framework (HEQSF).

About the publication

Kagisano is a research journal of the CHE. Papers published in *Kagisano* debate and discuss topical issues in higher education. The papers are developed from presentations at conferences or research colloquia organised by the CHE. Manuscripts that are submitted to be considered for publication in an issue of *Kagisano* are peer-reviewed by external experts as well as by internal researchers within the CHE. *Kasigano* is not yet on the list of South African journals approved by the Department of Higher Education and Training for subsidy purposes.

Disclaimer

Views expressed in this publication are those of the authors of the different papers in their individual capacities. They are not necessarily the views of the CHE. Furthermore, the CHE bears no responsibility for possible inaccuracies in the data and /or figures presented, nor for the possible gaps and/or flaws in the arguments proffered in the papers published in this issue of *Kagisano*.

ISBN: 978-1-928533-79-5

Publication date:

Contact details:

Council on Higher Education
1 Quintin Brand Street
Persequor Technopark
Brummeria
Pretoria
South Africa
Tel: 012 349 3840
www.che.ac.za

Foreword

Globally, the discourse on the relationship between the Fourth Industrial Revolution and higher education has steadily gained momentum over the last decade. The Fourth Industrial Revolution heralds significant changes to society and the natural environment, which higher education is expected to respond to. For example, it has redefined the workforce and the set of skills needed for the future. This has implications for higher education because one of its goals is to produce graduates who possess the set of skills required by the labour market at any point in time, including for the future. Therefore, it is important for higher education to adapt to the new realities of being required to produce the set of skills needed for the future.

The Council on Higher Education (CHE) recognises the critical importance of the discourse on the relationship between the Fourth Industrial Revolution and higher education, for the future of higher education in South Africa. It is for this reason that Council deliberated this matter and resolved that the discourse should be deepened and should include an understanding that, within the context of South Africa, the Fourth Industrial Revolution is one of a range of critical factors that are likely to have a bearing on the future of higher education. Even as the Fourth Industrial Revolution unfolds, higher education in South Africa should still take into account the importance of responding to other imperatives such as transformation; sustainable development; mitigation of, and adaptation to climate change; and promoting social justice and democracy, to mention a few. Leveraging the Fourth Industrial Revolution in higher education should not be at the expense of pursuing these national imperatives.

As part of deepening the discourse in a manner consistent with the guidance provided by Council, the CHE convened a colloquium on 1 September 2020 at which participants engaged with different perspectives on the Fourth Industrial Revolution in relation to higher education. The key message from the colloquium echoed the position of Council that in considering how higher education in South Africa responds to the technological developments associated with the Fourth Industrial Revolution, there should be concomitant cognisance of other important factors such as transformation, sustainable development, and promotion of social justice and democracy.

Kagisano No. 13 contains scholarly papers developed from the presentations and deliberations at the colloquium held on 1 September 2020. These papers argue different perspectives from the viewpoints of the respective authors. The publication therefore serves the purpose of providing one other means of deepening the discourse on the Fourth Industrial Revolution and higher education. Readers of the fourteen articles in *Kagisano No.13* are likely to recognise the influence of the Covid-19 pandemic on the discourse, with some of the articles arguing that the pandemic has had the effect of 'settling the debate' on the Fourth Industrial Revolution in relation to higher education. Other articles in the same publication contend that although higher education used some technological developments associated with the Fourth Industrial Revolution in effectively responding to the Covid-19 pandemic emergency, it does not necessarily mean that higher education should uncritically believe in the Fourth Industrial Revolution as the sole determinant of its future in South Africa. These divergent worldviews indicate that there is need to continue with the discourse on the relationship between the Fourth Industrial Revolution and higher education.

Readers who wish to comment on any of the articles in *Kagisano No. 13* may contact the relevant

author or authors directly through the email addresses provided in the articles. They may also submit the comments to the CHE by emails addressed to research@che.ac.za.

The CHE expresses its sincere appreciation to all authors who have contributed articles published in *Kagisano No. 13*; and to the editorial panel that reviewed all articles, recommended significant revisions, and selected the ones that are published in this volume. The CHE also acknowledges the important role played by staff in the Research, Monitoring and Advice (RMA) Directorate in convening the colloquium in 2020, and in managing the processes leading to the publication of this volume. The Monitoring, Research and Advice Committee (MRAC) of Council is thanked most sincerely for overseeing this project for its entire duration.

Dr Whitfield J Green

Chief Executive Officer

May 2022

Contents

Deepening the Discourse on the Fourth Industrial Revolution and Higher Education in South Africa

N. Wayi-Mgwebi*, & A. Saidi**

*School of Computing and Mathematical Sciences, University of Mpumalanga

** Council on Higher Education

Corresponding author: Saidi.A@che.ac.za

Abstract

This article serves as an introduction to the papers published in the 13th issue of the CHE's research journal, *Kagisano*, which is on the theme of the Fourth Industrial Revolution and higher education in South Africa. It briefly defines and unpacks the Fourth Industrial Revolution as a notion and its implications to higher education globally and locally. It argues that, given the history of this country and the necessary emphasis on transformation of higher education, the discourse should be on how the notion of the Fourth Industrial Revolution may be advanced within the broader context of transformation of society and higher education. It further explains the initiatives of the CHE aimed at deepening this type of discourse. These include convening a colloquium. The presentations at the colloquium have been developed by the authors into the scholarly papers published in this issue of *Kagisano*. It lastly identifies and discusses the recurring themes from the papers published in this volume. These include governance, changing paradigms, artificial intelligence, block chain technology, the digital divide and cybersecurity.

Keywords: Fourth Industrial Revolution, higher education, cybersecurity, artificial intelligence, block chain technology, digital divide, transformation

Introduction

In 2016, Klaus Schwab, described a paradigm of technological evolution that promised to merge the physical, digital, and biological spheres, impacting all disciplines, and disrupting many aspects of human existence (Schwab, 2016). This has been referred to as 'The Fourth Industrial Revolution' (Schwab, 2016). The concept of the Fourth Industrial Revolution has rapidly evolved from a loosely used and often misunderstood catchphrase, to a phenomenon that is rapidly manifesting in all aspects of day-to-day life of human beings.

A significant proportion of the technologies driving the Fourth Industrial Revolution has been, and continue to be, developed by researchers within higher education institutions. As a result, there is a reasonable expectation that higher education should be the driver of the technological changes within the context of the Fourth Industrial Revolution (Gleason, 2018). At the same time, there is an acknowledgement that, since the hallmark of the Fourth Industrial Revolution is disruption of the *status quo*, the potential of higher education to meet the demands of driving the technological developments is contingent on accepting and effecting changes in the academic traditions, values, and pedagogy (Penprase, 2018). Therefore, if higher education has to remain the driving force behind the Fourth Industrial Revolution, it should be prepared to adopt changes in the way it conducts its core functions, as necessitated by the developments in technology. For example, higher education curricula and pedagogy will need to be restructured to prepare students for the job market of the future, which

cannot yet be defined at this stage (Butler-Adam, 2018). Similarly, the mono-discipline focus will have to give way to multi-disciplinary education, where education and training aim at developing diverse backgrounds and strong mixes of skills for students (Total, 2018). In order to be successful in the era of the Fourth Industrial Revolution, students who study the basic and applied sciences, for example, also need to understand the political and social natures of the world; and those who study humanities and social sciences need to have good grasp of the foundations on which Artificial Intelligence is based, and how it operates (Butler-Adman, 2018).

Another significant implication of the Fourth Industrial Revolution as it relates to higher education is that it has the potential of rendering the linear 'higher education to employment and career model' redundant. This is because the fast pace of change that goes with the Fourth Industrial Revolution will require concomitant rapid expansion of the existing initiatives for updating skills of individuals after they had graduated. Within the scientific and technical education, there will be a need to educate and re-educate students to help develop and shape the use of the rapidly developing technologies. Accordingly, pathways for students to re-engage with their institutions after graduation will become imperative, and will provide updated skills to workers, as well as new channels for younger students and academics to engage with the fast-changing realities within the industrial and corporate sectors (Universities United Kingdom, 2018).

The discourse on the Fourth Industrial Revolution and higher education in South Africa

The main thrust in the discourse on the Fourth Industrial Revolution and higher education in South Africa is that the Fourth Industrial Revolution is a phenomenon of much significance because it is set to redefine the workforce and the skills needed for the future. This has implications for higher education because a key component of the functions of higher education institutions is to produce the skills required by the labour market at any point in time, including for the future. If, in the wake of the Fourth Industrial Revolution, higher education is not able to adapt to the new realities, and to produce the sets of skills needed for the future, it risks becoming redundant and irrelevant to the society of the future (Butler-Adam, 2018). This view places the Fourth Industrial Revolution as almost the only and all-powerful factor that has bearing on the future of higher education. It has the implication of rendering other concepts and organising principles that have helped shape higher education in the last couple of decades as irrelevant in term of reimagining the future of higher education in South Africa. However, a closer look at those other concepts and organising principles, notably transformation, sustainable development, mitigation of climate change, greening of the economy, social justice, and democracy, reveals that these remain relevant and have the potential to contribute significantly to the reimagination of higher education of the future, not only in South Africa but globally, even as the Fourth Industrial Revolution unfolds (Gillwald, 2022; Maharajh, 2022).

Another perspective has been to view the Fourth Industrial Revolution as a driver of societal transformation, including in higher education. This view then places the Fourth Industrial Revolution as part of the broad agenda for the transformation of higher education in South Africa, which entails (a) promoting equity of access and fair chances of success to all seeking to realise their potential through higher education, while eradicating all forms of unfair discrimination and advancing redress for past inequities; (b) working towards meeting national development needs, including the high-skilled employment needs presented by a growing economy operating in a global environment,

through well-planned and coordinated teaching, learning and research programmes; (c) supporting a democratic ethos and culture of human rights by educational programmes and practices conducive to critical discourse and creative thinking, cultural tolerance, and a common commitment to humane, non-racists and non-sexist social order; and (d) advancing all forms of knowledge and scholarship, and in particular addressing the diverse problems and demands of the local, national, southern African contexts and upholding rigorous standards of academic quality (Department of Education, 1997).

The technological developments that constitute the Fourth Industrial Revolution challenge the *status quo* of higher education and have implications for future provision of skills for the workforce. Being responsive to the Fourth Industrial Revolution will require restructuring the curricula and pedagogy, diversifying modes of delivery, as well as redefining and reconfiguring the study disciplines. It will also require a shift in the mindset of people from seeing education and training as a journey with a definite end destination, to one that does not have an end. This would mean embracing lifelong learning because new technologies would necessitate that graduates constantly go back to 'school' to learn the skills and competencies required to make effective use of the new technologies (Butler-Adam, 2018). The disruptions of the *status quo* that the Fourth Industrial Revolution is expected to bring about to higher education, and the structural and other forms of change that higher education will have to undergo in response to the Fourth Industrial Revolution, can be viewed as other dimensions of transformation, with the same ultimate goal of increasing the ability and capability of the higher education system to respond to the moral, political, social and economic demands of the democratic South Africa. Therefore, in principle, it should be possible, and indeed desirable, to advance the Fourth Industrial Revolution, within the broader context of transformation.

Higher education institutions in South Africa have had experiences of engaging in technology-driven transformation of the core functions of higher education long before the Covid-19 pandemic. Technology-based transformation for teaching and learning in South African higher education institutions can be traced to as far back as 1998 when the University of Pretoria introduced a Learning Management System (LMS) known as WebCT for distance learning (Bagarukayo & Kalema, 2015). Several institutions followed suit by adopting different LMS tools aimed at supporting learning. The tools were mainly used as electronic repositories of study material and for conducting some online assessments. In most of these institutions there was resistance to using these tools and thus they were not fully utilised. Some of the cited contributors to the poor adoption of these tools are poor computer skills, poor understanding of the tools, and technophobia especially for advanced in terms of age (resistance from ages above 40) (Dlalisa & van Niekerk, 2017). There was thus a need for training, cultural change, or mind transformation. Bagarukayo & Kalema (2015) also recommend a need for supportive institutional leadership, and awareness programmes, as part of change management.

The CHE's programme to deepen the discourse

The CHE identified the discourse on the Fourth Industrial Revolution and higher education as critical to the future of higher education in South Africa. It therefore came up with a programme to deepen the conversation. The programme entails providing platforms for engaging with different perspectives on the subject matter. These include CHE-facilitated colloquia and publication of original papers in its research journal, *Kagisano*. The first colloquium was held on 1 September 2020 where several scholars presented, and others engaged their ideas. After the colloquium, the presenters were requested to develop their presentations into scholarly papers to be considered for publication in *Kagisano* 13.

Some of the respondents at the colloquium were also asked to develop any key idea they might have taken home from the colloquium into scholarly papers to be considered for publication in the same research journal of the CHE.

A significant number of manuscripts were received from presenters and respondents at the colloquium held in September 2020. These were subjected to double blind peer review process which resulted in the selection of the thirteen papers published in this issue of the research journal of the CHE.

The influence of the Covid-19 pandemic on the discourse

Although the discourse on the Fourth Industrial Revolution and higher education preceded the Covid-19 pandemic, it is clear that the pandemic has had much influence on the discourse not only in South Africa but also globally. As Marwala (2022) observes, the Covid-19 pandemic brought urgency to matters related to the Fourth Industrial Revolution that had been discussed or planned for the future. In other words, it brought the future forward, and changed the nature of the discourse from focusing on interrogating the prospects and challenges of embracing the Fourth Industrial Revolution technologies, to quickly identifying which of those technologies could be adopted and utilised in enabling teaching and learning, research, community services, and student support services 'just-in-time.'

Higher education is one of the sectors that were forced to adopt online practices when the world went into lockdown owing to the Covid-19 pandemic. Suddenly there was an unavoidable need for teaching and learning to be conducted online. As indicated above, most of the higher education institutions in South Africa already had some form of Learning Management System (LMS) in place, although most were not yet fully utilised. This is a case that brings truth to the famous quote by William Gibson that **'the future is already here; it is just not evenly distributed.'**

This Covid-19 induced change of the course of the discourse is reflected in some of the papers in this issue of the CHE research journal which focus on how higher education institutions have made and continue to make use of technologies associated with the Fourth Industrial Revolution in teaching and learning, and in the provision of student support services during the time of the pandemic.

Recurring themes in the discourse

Globally and locally, the literature on the Fourth Industrial Revolution and higher education contains several recurring themes including governance, changing paradigms, artificial intelligence, block chain technology, the digital divide and security. These themes stand out also in the papers published in this issue of *Kagisano*.

Governance

Regarding 'governance' of higher education institutions, the paper by Kulati recommends that higher education institutions should be agile in their governance in order to be able to effectively respond to the fast-changing needs of society. He argues that universities are characterised by bureaucracy and suggests that agility in the context of these institutions remains elusive. This affected some institutions' responses to the Covid-19 emergency as some applied a blanket approach in their management of the crisis.

The article by Maharajh also alludes to the requirement for the Fourth Industrial Revolution to be governed by policies that take cognisance of the socio-economic realities prevalent in South Africa.

It views the Fourth Industrial Revolution as a phenomenon rooted in capitalist and neo-liberal ideologies with a belief of technology as a panacea for challenges such as poverty, unemployment, and inequality. Drawing on lessons from economic history, the paper highlights that the unfettered belief in technology has resulted in the exacerbation of the very challenges of poverty, unemployment, and inequality. The paper therefore calls for technological developments that are assessed and found to be appropriate for use in advancing the goals for sustainable development, addressing the scourge of inequality, and creating jobs and livelihoods for human beings.

On the same theme, the paper by Gillwald deplores the fascination with the Fourth Industrial Revolution that is apparent on societies including South Africa. The concern is that such fascination is dangers when it occurs without having in place a well thought out governance policy that takes into consideration the unique characteristics of South Africa and its higher education institutions. The paper cautions that this will likely have the consequence of reversing the gains that South Africa had registered in terms of addressing the many socio-economic challenges that the majority of the people in the country had been experiencing as a result of the legacy of apartheid.

On the other hand, the paper by Marwala presents a reflection on how the University of Johannesburg navigated through the challenges of the nation-wide lockdown. It reflects on the level of preparedness of the institution to address the new and complex restrictions facing teaching and learning. Some of the factors hindering the ability to harness technology as means to address the challenges, are critically discussed. According to Marwala the pandemic demonstrated that online and blended learning is not merely a matter of shifting a contact course online. He argues that it requires distinctive pedagogical and digital strategies, assessment modalities, and organisational governance and support to ensure quality, relevance, and accessibility. He also notes that some of the lessons learnt from the emergency remote learning experience will result in changes in the institution that will be adopted even beyond the pandemic.

In their paper, Kadyamatimba and Ochara demonstrate how the governance of the Fourth Industrial Revolution projects within institutions should be integrated in the overall institutional governance system. A model for realising such integration is proposed and presented in the paper.

Higher education paradigms

On the theme of 'higher education paradigms' the article by Zongozzi contends that, while South African higher education system continues to address challenges of inequality and inequity in higher education, other education systems elsewhere in the world are partaking in a new education paradigm dubbed 'Education 4.0'. The article explains that the Education 4.0 movement is fuelled by the Fourth Industrial Revolution. Zongozzi describes this shift as one characterised by 'fun, smart, inspiring, and empowering learning experiences'. He developed a conceptual framework of Education 4.0 within the context of transformation of higher education in South Africa. He proposes that a fusion of technology, multiplicity of sites, non-discriminatory learning, lifelong learning, student centeredness and Education 4.0 could be the much-needed response to the transformation imperatives of higher education in South Africa. He also makes the observation that Education 4.0 requires evidence-based practice that culminates in high-quality scientific research, good policies, infrastructure development and capacity building.

Gillwald echoes the same sentiments as of Zongozzi as she argues that there is a need for research on policy relating to the Fourth Industrial Revolution. She argues that the knowledge system in South Africa has failed to provide the necessary research and education to inform national public policy and the global governance of digital public goods. The argument is that there has been very little critical academic and policy discussion on the World Economic Forum's conceptualisation of the Fourth Industrial Revolution. She argues that institutions globally, including universities have been sold the futurist vision of the Fourth Industrial Revolution, and it is necessary to interrogate the underlying principles and assumptions before going along with it. Such interrogation would reveal, among other things, that without a context-specific policy governing initiatives to advance the Fourth Industrial Revolution, the envisioned bright future may not be realised, and the Fourth Industrial Revolution may not deliver real digital transformation for all.

The article by Kulati also explores the discourse on Education 4.0, and of the University as a Platform (UAAP). He provides a critical review of these emerging paradigms; and further examines models and theories of adaptation, before concluding that the lack of agility and ability remain critical stumbling blocks for universities as they march towards leveraging the Fourth Industrial Revolution.

In their paper, Sibanda and Fon advocate for a shift towards technology-based teaching and learning in higher education, building on the emergency remote teaching and learning experience that institutions acquired during the Covid-19 pandemic. They, however, also identify some challenges that would have to be addressed in order to optimise the outcomes of technology-based, and technology-driven teaching and learning.

Artificial intelligence

On the theme of artificial intelligence as one of the leading technologies for the Fourth Industrial Revolution, the piece by Pillay examines the advancement of artificial intelligence within higher education institutions. It recommends the use of artificial intelligence in improving the effectiveness and quality of service in such areas as student support and intelligent tutoring, monitoring the performance and success of students, predicting student success and failure, and automating the marking of assessments. The paper argues that the full potential of artificial intelligence in improving teaching and learning, assessment, and student support services, remains unrealised. It therefore urges institutions to make the necessary investments in artificial intelligence.

The paper by Kilfoil provides examples of two artificial intelligence tools that have already been implemented at the University of Pretoria. One is a chat-box tool based on Facebook messenger, which presents a real-time student support platform with frequently asked questions. The other is a chat-box Library tool for customer service and marketing, which is also used for projecting presentations. The paper by Kilfoil also argues that applying artificial intelligence effectively in any field requires inter-disciplinary collaboration between data engineers, data scientists and a diverse range of stakeholders and domain experts.

Blockchain technology

The paper by Ouma, Odhiambo, Kadyamatimba and Ochara advocates for use of blockchain innovative pedagogies in learning platforms that will meet the technological skillsets of students in the age of the Fourth Industrial Revolution. Within such platforms, institutions can effectively administer courses,

and industries will be able to inform university curricula or offer courses tailored to their needs. The blockchain will ensure authenticity of the course content. Furthermore, it can be used to accredit instructors, and provide provenance to courses offered by institutions. The students will also be able to study at their own pace without fear that their previous tasks and assignments will not count towards the certificates offered. In a higher education system anchored in blockchain technology, everyone could have a stake either directly or indirectly.

Digital divide

The paper by Maharajh argues that the Fourth Industrial Revolution has made visible a dimension of inequality that people were not fully aware of previously. This dimension of inequality in the form of the digital divide. The papers argues strongly that the benefits of the Fourth Industrial Revolution which proponents tout about so glowingly are likely to accrue to the rich strata of society, leaving the rest of the population condemned to a pre-Fourth Industrial Revolution age.

The article by Gillwald boldly asserts that the Fourth Industrial Revolution is not the vehicle for realising the much-touted digital transformation of society. Instead, it will entrench the digital divide.

The contribution by Obi highlights that the digital divide cause students from disadvantaged communities not to be adequately prepared for the rigour of higher education in the Fourth Industrial Revolution context. Often, the students from disadvantaged communities have poor background in mathematical, computing, communication, and entrepreneurial skills. This makes them lag behind in terms of mastering the technologies associated with the Fourth Industrial Revolution.

The article by Simelane, Ojo and Onwuegbuzie discuss how, during the nation-wide lockdown, students who had limited or no access to electronic devices, Internet access and electricity, were disadvantaged. They sharply raise the point that during the nation-wide lockdown, students were confided to their homes. The research reported in the article found that homes of students from poor families were not conducive environments for learning. Some students had no desks nor chairs for use during studies. Simelane, Ojo and Onwuegbuzie therefore conclude that the push towards the use of e-learning technology could exacerbate inequality.

In their piece, Sibanda and Fon argue that the digital divide is manifested not only in terms of lack of physical access to devices, but also in terms epistemology which is about knowledge and competencies that would enable academics and students to be able to make the best out of digital technologies. Sibanda and Fon argue that there are still large sections of society that are not computer literate, for example, which affects their productivity at work, or their effectiveness in making use of digital learning resources.

Cybersecurity

In their paper, Kadyamatimba, Patala, Madzvamuse and Ochara point out that one challenge that higher education institutions have to contend with as they migrate to cloud computing, which is one of the technologies under the Fourth Industrial Revolution, is that of cybersecurity. They assert that data and information constitute important assets for higher education institutions, and their security, particularly in a cloud computing environment should be a preoccupation of each and every higher education institution. They propose a model that higher education institution may adopt to guide them in putting place cybersecurity systems.

Conclusion

While the intention of the CHE was to initially deepen the conversation on how the Fourth Industrial Revolution could be advanced within the context of the agenda for the transformation of higher education in South Africa, the Covid-19 pandemic changed the focus to that of building on the experiences of higher education institutions during the pandemic as the stepping stone into a future in which the Fourth Industrial Revolution is a key factor influencing how higher education institutions pursue their teaching and learning, research and community engagement mandates. Due to Covid-19, the notion of blended learning, which has been under discussion in higher education institutions for decades, suddenly become a pragmatic solution to delivering content. Higher education institutions were presented with a rare opportunity to put theory into practice, while academic and support departments have had no choice but to adapt. With the capabilities of the Fourth Industrial Revolution and the new adopted culture of online learning, there is a need for higher education institutions to expand the scope of the new paradigm under which technology can be harnessed such that teaching and learning, and other academic activities can continue regardless of the limits of time, place, and mobility.

There is a concern that the Fourth Industrial Revolution may lead to loss of jobs as technology replaces human labour. Technological unemployment is not a new phenomenon and has characterised previous industrial revolutions and manifested as a hollowing out of middle-income jobs. In the same breath, it is important to note that the Fourth Industrial Revolution has broadened the horizons of time and place, allowing workers to seek opportunities beyond geographic borders, and outside of traditional employment contracts. New forms of work such as gig work, crowd work, remote work and platform work have become widely prominent. These shifts have challenged the labour market, shifting the balance of power between employers and workers to the advantage of the employers. This has coincided with a declining influence of trade unions and consequently, the conditions of some types of employments have become precarious.

The Covid-19 pandemic has further challenged working conditions with the move to remote work models. Collectively, these conditions challenge the readiness of the workforce to participate constructively in a digitally disrupted labour market. It is generally accepted that many jobs of the future do not exist yet, while many are at threat of becoming obsolete. The role of higher education in producing graduates that possess the right skills to participate meaningfully in the labour market is central to mitigating the negative impact of the Fourth Industrial Revolution. This calls for revisiting how academics in higher education teach, what they teach and where they teach.

Questions remain on how to design the university of the future that is fully responsive to the Fourth Industrial Revolution and to the changing demands of society, the governance systems for the future university, and the requisite graduate attributes taking into consideration the future of work. It appears more likely that the discourse will focus on these questions as the world emerges from the emergency of the Covid-19 pandemic.

References

Bagarukayo, E., & Kalema, B. (2015). Evaluation of elearning usage in South African Universities: A critical review. *IJEDICT*, :168-183

Butler-Adam, J. (2018) The Fourth Industrial Revolution and education. *South African Journal of Science* 114(5/6)

Department of Education. (1997, August). Education White Paper 3: A Programme for Higher Education Transformation. Pretoria: Government Printers

Dlalisa , S., & van Niekerk, B. (2017). Factors affecting the post-implementation adoption and usage of blackboard amongst academics at du. *9th Annual Teaching and Learning in Higher Education Conference.* Durban: UKZN

Gillwald, A. (2022): The Fourth Industrial Revolution: Why it Cannot Deliver Digital Transformation to South Africa *Kagisano* 13 (this volume)

Gleason, N. W (2018). *Higher Education in the Era of the Fourth Industrial Revolution*, Singapore: Palgrave Macmillan

Joachim Bjørge Ulven, G. W. (2021). A Systematic Review of Cybersecurity Risks in Higher Education. *Future Internet*,: 13-29.

Krishnaveni, M. a. (2010). Usage of ICT for Information Administration in. *International Journal of Environmental Science and Development*,: 282-286

Maharajh, R. (2022) Techno-Economic Change and the Transformation of Higher Education: Early 21st Century Challenges

Penprase B.E. (2018) The Fourth Industrial Revolution and Higher Education. In: Gleason N. (ed) *Higher Education in the Era of the Fourth Industrial Revolution*, Singapore: Palgrave Macmillan

Schwab, K. (2016). *The Fourth Industrial Revolution.* Geneva: World Economic Forum

Schwab, K. (2018). *Shaping the Future of the Fourth Industrial Revolution: A Guide to Building a Better World*. Switzerland: World Economic Forum

Total, A.E.A. (2018) A Brave New World: Technology and Education. *Trends Shaping Education Spotlights* 15:1-12

Universities United Kingdom (2018) *Solving Future Skills Challenges*, UUK: London

Locked in a Pandemic: Unlocking Innovation in Higher Education

T. Marwala

University of Johannesburg

tmarwala@uj.ac.za

Abstract

As the Coronavirus engulfed much of the globe in 2020, the South African government declared a national state of disaster and an initial lockdown of three weeks. With this occurring just eight weeks into the academic programme, the higher education sector was sent into a tailspin. Difficult decisions had to be taken to fundamentally reimagine processes, indicative of the Fourth Industrial Revolution or the age of disruption that the higher education sector simultaneously found itself in. At the University of Johannesburg, over a week, an urgent review of all business continuity plans domains across the institution was conducted to make provision for the national lockdown measures and for the rapid containment of on-campus risk. Based on a qualitative approach and using the University of Johannesburg as a case study, this paper explores the higher education sector's response to these sweeping changes.

Keywords: Coronavirus, higher education, disruption, Fourth Industrial Revolution

Introduction

As the first rumblings of Covid-19 reverberated through South Africa in early 2020, forcing the country into a nation-wide lockdown, the higher education sector already had contingency plans in place. Throughout the world as countries locked down and economies came to a standstill, it became apparent that schools, higher education institutions and businesses that could, had to shift to remote methods of teaching, learning, and working. Where the shift could not be made, jobs would bleed, and academic programmes would come to a standstill. At the time, the plan was viable based on the assumption that lockdown would last for three weeks only. With some element of naivety, many expected that after three weeks of lockdown there would be a return to normal. However, the pandemic has wrought change and distorted normalcy forcing some courses to go online, and a rejig to the academic calendar. It soon became apparent as the lockdown stretched into weeks, and then months, that there was a need to fundamentally rethink higher education. Over the years, during conferences, there have been written papers and lengthy discussions about the need to overhaul the current structures in higher education. Yet, thrown into the deep end, the reality was certainly a shock. The sweeping changes 2020 brought presented a new epoch for higher education.

Motala and Menon (2020: 82) reflected extensively on this new normal, as they wrote:

> 'Times of war, conflict and system shocks have brought widespread changes to societies, and questions are being raised about whether Covid-19 will transform universities as the Black Death did in the Middle Ages.'

In many recent reports traversing the changes industries have seen with the Coronavirus pandemic, the detail on the higher education sector has been scant. This was incredibly surprising as the sector

was certainly not immune from the impacts of the pandemic. There certainly has been a shift. Yet, the reality of dealing with the pandemic has been far different from what anyone could have anticipated. This was unchartered territory, even at a university that prides itself on a constant reimagining of the future. It was not a question of potential shifts in teaching and learning or imagining how to adapt to an increasing digital age; the University was in the thick of it, seemingly locked in the pandemic, with immediate decisions needing to be taken.

As revolutions go, there are synergies between what are seen as essential core skills that students and academics likewise need to develop between the Fourth Industrial Revolution and the abrupt disruption that the Covid-19 pandemic has brought in its wake. It is often wrongly assumed that the Fourth Industrial Revolution has a finite beginning and end. The reality is that society slip and slide between the revolutions and it is clear that the speed at which technologies develop far outpace the human ability to predict what the higher education sector needs to do in order to close the gaps. The sector cannot always be playing a catch-up game. Vinge (1993) states that, 'We are on the edge of change comparable to the rise of human life on Earth.'

The merging impact of multiple technologies has the potential to shift the sector to a position which is termed the 'Singularity.' Miller (2012) defines this as the point in time when machines will be considered super-intelligent, or at least as intelligent as humans, which could reimagine civilization. The future has now acquired a significantly distorted dimension as the Covid-19 pandemic brings with it crashing economies, massive job losses, and financial uncertainty for higher education. In this context, the responsiveness of the higher education sector, and in particular of its leaders, is absolutely non-negotiable.

This uncertainty brings with it fundamental questions that should be answered. Do higher education institutions trundle about assuming that the world is normal, or do they embrace the shifting realities and quickly reflect on what changes are required? Accusations are regularly levelled at the sector for having little agility, elephant- or tortoise-like in its responsiveness to change and locked within the irrelevance and elitism of 'the ivory tower.' It is important that universities change how they work, what they teach and how they teach. At the same time, there is a need to consider how students learn and what is the context in which this learning takes place. But this is merely the beginning. It is also important to reflect on the nature of research that higher education institutions conduct, and its concomitant benefits to society and the natural world, while the changes unfold. Time is of essence, and as the sector faces these changes.

Harnessing the Fourth Industrial Revolution to navigate the pandemic

The Fourth Industrial Revolution entered the popular lexicon in South Africa through President Cyril Ramaphosa, who included it as part of his proposed national development strategy after assuming the Presidency in 2017 (Sutherland, 2020). This generated extensive debate and projections about what the Fourth Industrial Revolution would mean for the future in industry, education and society, with critics cautioning that it might exacerbate existing inequalities and social cleavages.

As has been noted, the Fourth Industrial Revolution is characterised by the expansion of 'exponential technologies' and the effects of their integration (Kayembe & Nel, 2019; Yusuf *et al*., 2020). This includes, but is not limited to, artificial intelligence (AI), blockchain technology, the Internet of Things (IoT), robotics, increased automation, and the centrality of Big Data. As Yusuf *et al*. (2020) and Xing *et*

al. (2018) argue, the Fourth Industrial Revolution differs from preceding industrial revolutions in that it is not only about the proliferation of new technology that restructures work and allows machines to surpass human effort, but rather also about how enhanced information storage, processing and integration capacity affects work, daily life, and intellectual development. Information and data are the building blocks of this new period in human history, where technology is currently developing at a faster rate than human beings are able to fully grasp and harness (Schwab, 2016). It is true that there may be adverse effects on society as a result of these changes, heralding the need for leadership and scholarship that can support effective integration into a world still in the making.

Higher education has played a pivotal role in this process, given that universities have both been the location of many important innovations, and have had to respond to the impact of major technological and economic change on issues such as graduate employability and skills relevance (Ramirez, 2018; Menon & Castrillon, 2019; Yusuf *et al*., 2020). This occurs within the context of increased massification of higher education which has, in certain cases, contributed to rising graduate unemployment, low economic returns to education, and increased pressure for graduates to specialise or otherwise set their skills apart in order to qualify for more lucrative employment (Xiong *et al*., 2020). As degrees became tickets to greater earning potential and social status, demands for expanded access to higher education grew, most recently in South Africa during the #FeesMustFall movement that catalysed the announcement of free university education and propelled the country towards its current period of increasing massification. This was not without its own challenges, however, as historic inequalities of race, class, gender, and geography continue to cut across system-level issues of access, quality, equity, and innovation (Menon & Castrillon, 2019). It has become increasingly apparent that South African universities (like others around the world) need to be agile in working with the profile of students they have to achieve the social and economic goals they have set out.

The Fourth Industrial Revolution has deepened these complexities even as it provides new opportunities for development and innovation in higher education. The shift to an economic and industrial climate characterised by increased automation poses a threat to existing employment streams, while both the nascent and existing labour force need to adapt to the demands of rapidly emerging new industries, jobs, and skill sets (Xing *et al*, 2018; Zhao, 2018; Sutherland, 2020). Critics such as Sutherland (2020) have also argued that without resolving the existing inequalities that currently plague South Africa, the Fourth Industrial Revolution will only compound poverty, unemployment and underemployment, and volatile economic growth. However, the opportunities offered by the Fourth Industrial Revolution may chart a course towards enhanced growth and social development if higher education institutions (Higher education institutions) can harness new technologies and approaches towards educating graduates for the future. As Zhao (2018) and Yusuf *et al*. (2020) argue, many universities remain stuck within outmoded forms of content delivery and assessment. Menon and Castrillon (2019) also point out a deep distrust of the use of technology in higher education, with this seen to be watering down quality and inadequately replacing contact teaching and learning. In their reflection on adapting curricula to the Fourth Industrial Revolution, written a year before the Covid-19 pandemic, they foreshadow a critical shortcoming of the higher education landscape: the lack of flexibility and agility that would frustrate the smooth transition to online teaching and learning as a result of the pandemic and the resultant lockdown (Menon & Castrillon, 2019).

Some of the important things that the Fourth Industrial Revolution agenda has highlighted include a need for greater institutional and programme flexibility to remain responsive to changing

circumstances, industry needs and societal shifts. Moreover, learning needs to be multidisciplinary and allow space for regular upskilling, with students being required to learn beyond the narrow confines of traditional academic disciplines (Kayembe & Nel, 2019), adapt their learning to new modalities and be able to tailor their thinking towards problem-solving in dynamic situations (Yusuf *et al*., 2020). Scholars also emphasise the growing importance of multiple points of entry into employment streams, as well as opportunities for lateral professional movement that recognise and respond to changes in career pathways, qualifications, and life stages (Xing *et al*., 2018; Kayembe & Nel, 2019; Yusuf *et al*., 2020). There are also critical 'soft skills' that graduates will need to develop in order to adapt to increased automation and digitisation, such as ethics education and social responsibility. Taken together, this points to the need to develop a strategy for the Fourth Industrial Revolution integration that weaves together academic, professional, economic, social, and moral imperatives for enhanced development.

The Covid-19 pandemic presented a decisive road-testing of the University of Johannesburg's preparation for the Fourth Industrial Revolution, in that it compelled the institution to apply those measures, processes and interventions that were in the process of being flighted for an unknown future date. University of Johannesburg has adopted the ADAPTIVE strategy for preparing for the Fourth Industrial Revolution: 'accessibility, digital literacy, acceleration, pan-regionalization, transformation, inclusiveness, vision, and engagement' (Xing *et a*l., 2018: 179). This strategy aims to facilitate preparation for the Fourth Industrial Revolution at a granular level, from offering a number of mobile technology applications to support teaching, learning and administration, to building high-level partnerships with other institutions, industry leaders, regional stakeholders and local communities. The institution has further invested in developing the kind of learning infrastructure and networks that enables students to implement and refine what they learn in practical settings (Xing *et al*., 2018).

While the contact-mode innovations that the University of Johannesburg was working on as part of its commitment to the Fourth Industrial Revolution were disrupted by the pandemic, they became the springing board for the adaptation to online and remote operations necessitated by Covid-19. Research on the impact of the pandemic on higher education speaks to the disruptive effects it has had on teaching, learning, assessment, and research around the world (Crawford *et al*., 2020; Jena, 2020; Marinoni *et al*., 2020; Xiong *et al*., 2020). There are several important takeaways to highlight. Firstly, the pandemic has disrupted the mobility of students, affecting the uptake of international study, semester-abroad and internship opportunities. This has already begun to have short- to medium-term effects on students' academic choices, including where they choose to study, and the attractiveness of studying away from home during a period of uncertainty (Crawford *et al*., 2020; Xiong *et al*., 2020). It also impacts the labour market, increasing competition for local employment, internship and learnership opportunities.

Secondly, the pandemic has illustrated the uneven preparedness of institutions, systems, and entire countries for adapting to this kind of crisis. In a survey conducted with university leaders from 111 countries or territories, Marinoni *et al*. (2020) point to the comparatively poor preparation of African higher education systems to adapt to the 'new normal', relative to their European, Asian, and American counterparts. However, they fail to adequately contextualise the challenges these higher education systems have to contend with, including (but not limited to) weak and intermittent information and communications technology (ICT) infrastructure, poverty, rurality, and limited resources for institutions to offer substantive support to students and staff. What Marinoni *et al*. (2020) and Crawford *et al*. (2020) do argue, is that the pandemic will fundamentally alter modes of curriculum delivery, and that online

learning is a distinct phenomenon requiring fit-for-purpose design, delivery, and quality assurance. In their review of 20 countries' responses to the pandemic in higher education, Crawford et al (2020) highlight that those countries with established online learning modalities, or relationships between traditional universities and online providers, were more successful at adapting their programme delivery to the online mode. They also emphasise the importance of 'technology' being suited to context, making the example of countries such as Jordan where 'low tech' solutions such as the use of freeware (for example, Skype, Facebook, Google Classroom) were more successful because these worked with the technological infrastructure, such as mobile phones, that most students had to handle (Crawford *et al*., 2020). This view is supported by Jena (2020), who lists a number of interventions used in Indian higher education including radio and television broadcasts, virtual labs, and chatrooms, which expanded opportunities for students to engage with lecturers, experts, and peers on their coursework.

The University of Johannesburg's Quality Assurance Report on the Transition to Remote Teaching and Learning (2020) lists an impressive array of measures that were already in place when the lockdown was declared on 26 March 2020, as well as the rapid pace at which further efforts were made to keep the academic year on track while maintaining student and staff wellness and participation. Motala and Menon (2020) argue that one of the central factors underpinning the institution's 'organisational agility' in its response, was ongoing communication and collaboration among staff alongside strategic use of technology to support the institution in the transition to Emergency Remote Learning (ERT). This included zero-rating websites, creating an official information portal on the institutional website, providing support through Blackboard and the Library facilities, and engaging in data-driven decision-making. The institution's commitment to its planning for the Fourth Industrial Revolution also meant that it had established divisions dedicated to supporting the transition to online learning, such as the Centre for Academic Technologies (UJ, 2020).

Because at least 60% of University of Johannesburg's students are beneficiaries of the National Student Financial Aid Scheme (NSFAS), there were also severe socio-economic shocks experienced by students having to adjust to learning remotely. The institution attempted to mitigate these shocks through the provision of food parcels, data, and zero-rating websites, as well as laptops and tablets. More than one 'divide' needed to be bridged at any given moment, with the pandemic throwing existing inequalities into sharp relief. This provides an interesting parallel to critiques of the Fourth Industrial Revolution, in that the Covid-19 pandemic captured the same issues around equity, access and support. Current research demonstrates the importance of engaging with socio-economic challenges alongside technological development, as those most negatively impacted by the shift to ERT and online learning were also those students who lacked conducive learning environments at home, struggled to access money and food, and went to great lengths to stay on track with their learning in the absence of regular contact teaching. This experience was not unique to South Africa, either (Crawford *et al*., 2020; Marinoni *et al*., 2020), highlighting the importance of greater collaboration, sensitivity, and strategic planning in adapting teaching and learning to uncertain futures of multiple, sometimes interlocking natures. In Marinoni *et al*.'s (2020) survey, two-thirds of respondents from African higher education institutions reported that their institutions had closed until an effective online learning strategy could be established. This kind of interruption has lasting effects not only on student cohorts, but institutional resilience and reputation, and it remains to be seen what the impact of this interruption will mean for ensuring quality and stability in higher education on the continent. As Crawford *et al*. (2020: 10) argue,

> '[The Covid-19 pandemic] was also a demonstration of the impact of poorly resourced institutions and socially disadvantaged learners where limited access to technology and the internet impacted on organisational response or students' ability to engage in an online environment.'

Crawford *et al.* (2020) advocate for developing a cross-country, collective response to the pandemic that enables sharing of best practices and supporting developing countries in establishing effective alternatives to contact teaching and learning.

The pandemic experience has offered higher education institutions the opportunity, knowingly or not, to stress-test their capacity to adapt to the demands of the Fourth Industrial Revolution. It has demonstrated that online and blended learning is not merely a matter of shifting a contact course online, but requires distinctive pedagogical and digital strategies, assessment modalities, and organisational governance and support to ensure quality, relevance, and accessibility. The discussion to follow considers these issues in light of the experience of the University of Johannesburg.

Unlocking innovation

As the University of Johannesburg began to navigate the 'new normal', there were various challenges that had to be contended with. From a teaching standpoint, the institution grappled with the challenges posed for its assessment modalities. Even those with experience in blended teaching had limited or no experience of online assessment. Deep questions on how to assess applied competence online led to new innovations in some cases, and in other cases, a return to traditional models of assessment. Remote teaching significantly added to the burden of staff with large classes. Compared to staff, students experienced even significant difficulty with the new pedagogy that is managed through new technologies over different disciplinary and teaching methods across the modules. This may be because of devices, data, connectivity and bandwidth issues or insufficient time to prepare for remote learning (UJ, 2020). This was especially heightened considering that first-year students had only experienced about 7 to 8 weeks of normal contact teaching and were still finding their feet in terms of the University's vast electronic resources and the learning management system.

Then, of course, the institution faced the digital divide, which presents starkly in South Africa. The University of Johannesburg serves as a microcosm of this broader context. For many, limited access to data and devices posed a pressing challenge. Some take it for granted that these resources that they perceive as necessities are readily available to all. For others, tough decisions have had to be taken about whether to forego other needs in favour of data bundles, for example. While the institution responded to this with the distribution of devices and agreements with telecommunications companies to provide free data for this period, these are only short-term solutions. They do not constitute a perfect band aid.

Students and staff responded with tenacity as the institution have continually tried to pivot solutions to these challenges. The skewed access to technologies, bandwidth, devices, and coverage plagued higher education institutions across the country. These inequities of access have required institutions to reach beyond their mandates as universities and address an exacerbated problem of 'access', which was made more urgent and important to ensuring equity in teaching and learning.

Although the University website was zero-rated, its learning management systems were not. Added

to this, much of the data allocated by telecommunication companies were 'night owl' bundles, which can only be used from midnight to 05:00 in the morning. The important issue of devices and data requires a national intervention (UJ, 2020). Then, of course, is the challenge of context. Many students find themselves in settings that are not always conducive to learning. This is a national crisis requiring larger, more systemic interventions.

In spite of these challenges, the University of Johannesburg certainly rose to the occasion. The innovations it flighted enabled the institution to complete the academic year, making it one of just a handful of South African universities that were able to do so. In 2020, the pass rate was higher for the lockdown period than for the year before, and attendance was on par with previous years. In March 2020, this seemed like a near impossible task. Yet staff responded to the challenges of mastering and managing new pedagogies through new technologies by working harder and keeping much longer hours (UJ, 2020).

Before the pandemic, the University of Johannesburg was already in an era of disruption. One could argue that the pandemic served as a litmus test for preparedness of the institution. Like the previous industrial revolutions, the Fourth Industrial Revolution will change every facet of society, from the way human beings interact to how industries operate, and to the way human beings consume goods and services (Schwab, 2016). While the pandemic has changed the way institutions operate and forced them to introspect, it has provided an opportunity to adapt to the paradigm shift currently underway, to learn to manage uncertainty and chaos, and deal with the gravity of immense social, economic and health shocks on societies on the brink of change.

Long before the world could even imagine that a pandemic would hasten the shift to digital technology, Marwala and Xing (2017: 10) wrote about the implications of the Fourth Industrial Revolution on higher education. They argued at the time,

> 'Higher education in the fourth industrial revolution is a complex, dialectical and exciting opportunity which can potentially transform society for the better.'

This rang true throughout the institution's navigation of the lockdown and the shift to online teaching and learning. Unlike the pandemic, the paradigm shift that higher education should undergo in the Fourth Industrial Revolution stretches beyond just an adoption of technology.

Xing and Marwala (2017) detailed the changes that higher education institutions needed to adapt to keep up with the Fourth Industrial Revolution. This played an integral role in determining how the University of Johannesburg would navigate teaching and learning pedagogies during the pandemic. There was an argument not only for teaching and learning to be re-examined but for a revisiting of the current packaging of knowledge at higher education institutions in preparation for the future of work. Motala and Menon (2020) argue that institutions are generally able to plan for disruptions of a 'regular' nature, yet the pandemic has to a large extent been unexpected and difficult to plan for. They raise concerns about the long-term impact of this uncertainty on the sector.

Teaching and learning interventions

The University of Johannesburg began by developing an approach to blended learning – in other words, a live interaction that uses technology. This, however, did not prepare the institution in the least for a complete online offering. There was much more to interrogate with remote learning, without the

time usually afforded to testing models and processes. The institution did not have the luxury of trial and error, as the situation required 'just-in-time' decisions and effective action.

In the Fourth Industrial Revolution, the shift envisioned would encompass peer-to-peer interaction and one-on-one counselling. Technologies of the Fourth Industrial Revolution would be integrated into the learning process. The effectiveness of this was seen during the lockdown. For instance, the University's academics disseminated short videos, held Zoom calls, and communicated through WhatsApp with students. A number of academics discovered new technologies that could be deployed to afford students the opportunity to experience some aspects of their regular academic programme, such as online consultations with clients at law clinics and simulations in the health sciences (UJ, 2020).

In the years leading up to the pandemic and subsequent lockdown, the University of Johannesburg had begun piloting wearable technologies which have the potential to simulate real-life experiences. These technologies include augmented reality (AR). For example, the Faculty of Engineering and the Built Environment constructed the Simulacrum which will replicate realistic simulated mining conditions, providing students with a 'real-time' mining experience. Similarly, AR can supplement reality via superimposing computer-generated information over the physical context in real-time which can facilitate results exploration and interpretation. For example, virtual reality (VR) crosscut and stope blast wall simulation in the mining laboratory, is now in use. Students are taken through a sequence of identifying geological hazards, marking-up of the direction- and gradient lines on a smart-screen. Upon completion of the correct marking-up of the design, the student can sequence the blast with the correct blasting pattern and detonator delay and a blast is then simulated.

Of course, with the increased use of devices by students in campus, the institution implemented some blended teaching models such as Blackboard, an application that supports online teaching and learning. Through this application, podcasts of lectures can be uploaded, rollcall can be taken, and academics can monitor the progress of their students. In 2017, the institution launched its online campus. This served as an important template for the shift to online teaching and learning in 2020.

Interestingly, while the digital divide posed a challenge during the lockdown, there are arguments for increasing access to higher education in South Africa through mobile devices. Considering that smartphone usage is increasing in the country, there is an argument that mobile technology can offer greater access to campuses while innovatively countering apartheid spatial planning (Baran, 2014). With the implementation of fee-free higher education for the poor in 2017, higher education institutions had to interrogate whether there was sufficient capacity for more students, and at what cost. Here, online education resources can be pivoted to bridge the gap.

Though not all modules at the institution could move fully online instantly, the University of Johannesburg was fortunate to have a robust learning management system. In the first semester, which coincided with the lockdown, more than 1,500 modules were repurposed for completely online teaching. This required a repositioning of all support domains to ensure that academics and students could be assisted in multiple ways to make this rapid transition. For example, the library and IT repositioned their services in innovative ways to make resources accessible to both staff and students. The library provided training programmes for everyone, and academics were reminded of the Library App and the online accessibility of all library functions (UJ, 2020). The model of realignment of services normally provided in a bricks and mortar environment, replicated itself across all support domains.

System-wide and sectoral interventions

This has also been a time of innovation. Within the first four weeks, with the usage of 3D printers, the University of Johannesburg was producing personal protective equipment (PPE) and ventilators, for example. The ventilator project created by 3D printers has won an external tender bid of R30.5million. This is just one area where the University has ensured that it is at the forefront of this battle with the disease. Furthermore, an App that enables users to pull all the COVID-19 related research from institution was launched and is now fully operational.

The University of Johannesburg launched the UJ Press in October 2020. This will publish journals and monographs online. It will be interactive with hyperlinks to related literature and other resources that speak to the dearth of topics covered. Although this plan was long in the pipeline, it certainly speaks to the current context. While some might have a traditional model of a press in their mind, the Fourth Industrial Revolution allows one to publish peer-reviewed work, providing wider access to knowledge beyond the physical walls of a university.

Conclusion

The future of higher education will be determined by the choices the sector makes in response to threats such as the Covid-19 pandemic, as well as to rapid technological changes that are part of the Fourth Industrial Revolution. Does the sector stare bleakly into the future and continue as normal? Or does it embrace the future and reimagine itself in that future and contend with the tsunami of changes that the world is undergoing? The Fourth Industrial Revolution and the pandemic co-exist and will continue to reach into the future in unprecedented ways.

Of course, many of the systems that have been adopted during the pandemic period will continue to augment the academic programme in the future. Now, that the sector has weathered more than two years in the pandemic, the very notion of disruption seems less daunting. The Covid-19 experience has offered a moment in time to reflect on current systems and sector's preparedness for any paradigm shift on the horizon. As Motala and Menon (2020: 81) argue,

> 'COVID-19 is a global pandemic with no end in sight. It brings with it a prolonged period of disruption with a possible continuation of these levels of disruption prevailing in the foreseeable future.'

It could be argued that this can be taken a step further. While the pandemic may be uncertain, arguably the contemporary context dictates that these levels of disruption should be seen long into the future whether life returns to a semblance of normalcy or not. This is a pivotal moment for the higher education sector to redefine its systems and gear up in innovative ways to rise to the challenges both locally and globally.

The pandemic period has also seen renewed vigour towards fighting social injustices. Many more than before have sounded a clarion call for greater equality – across gender lines, racial lines, and class divisions. While the Covid-19 pandemic might itself become the object and subject of research, it can be argued that greater focus will be given to social justice issues, the utilization of technology for the good of all and finally, a quest for a just society. This will perhaps be the greatest definer of this new world order.

References

Baran, E. (2014). A review of research on mobile learning in teacher education. *Educational Technology & Society*, 17(4): 17–32

Crawford, J., Butler-Henderson, K., Rudolph, J., Malkawi, B., Glowatz, M., Burton, R., Magni, P. & Lam, S. (2020). COVID-19: 20 countries' higher education intra-period digital pedagogy responses. *Journal of Applied Learning & Teaching*, *3*(1): 1-20

Jena, P.K., (2020). Impact of Covid-19 on higher education in India. *International Journal of Advanced Education and Research (IJAER)*, 5(3): 77-81

Kayembe, C., & Nel, D. (2019). Challenges and opportunities for education in the Fourth Industrial Revolution. *African Journal of Public Affairs*, 11(3): 79-94

Marinoni, G., van't Land, H., & Jensen, T. (2020). *The Impact of COVID-19 on Higher Education Around the World: IAU Global Survey Report*. Paris: International Association of Universities (IAU)

Menon, K., & Castrillón, G. (2019). Reimagining curricula for the Fourth Industrial Revolution. *The Independent Journal of Teaching and Learning*, 14(2): 6-19

Miller, J.D. (2012). *Singularity Rising: Surviving and Thriving in a Smarter, Richer, and More Dangerous World.* Dallas: BenBella Books

Motala, S., & Menon, K. (2020). In search of the 'new normal': Reflections on teaching and learning during Covid-19 in a South African University. *Southern African Review of Education*, 26(1): 80–99

Ramirez, V. (2018). Sustainability standards: The new quality assurance for higher education in the fourth industrial revolution (the Fourth Industrial Revolution). Retrieved from: https://www.researchgate.net/publication/330924820_Sustainability_standards_the_New _Quality_Assurance_for_Higher_Education_in_the_Fourth_Industrial_Revolution_the Fourth Industrial Revolution

Schwab, K. (2016). *The Fourth Industrial Revolution*. Munich: Pantheon Verlag

Sutherland, E. (2020) The Fourth Industrial Revolution – The Case of South Africa. *Politikon,* 47(2): 233-252

University of Johannesburg (UJ) (2020). *QA report on the transition to remote teaching and learning*. University of Johannesburg. Retrieved 15 January 2021 from https://www.uj.ac.za/coronavirus/teaching-remotely/Documents/UJ%20QA%20Report%20on%20Teaching%20and%20Learning%20Final%2016%20Sept%202020.pdf

Vinge, V. (1993). *The Coming Technological Singularity: How to Survive in the Post-Human Era*. NASA Conference Publication, 10129: 11-22

Xing, B., Marwala, L., & Marwala, T. (2018). Adopt Fast, Adapt Quick: Adaptive Approaches in the South African Context. In Gleason, N.W. (ed.), *Higher Education in the Era of the Fourth Industrial Revolution*, 1st edition. Singapore: Palgrave Macmillan

Xiong, W., Mok, K.H., Ke, G., & Wun Cheung, J.O. (2020). Impact of COVID-19 Pandemic on International Higher Education and Student Mobility: Student Perspectives from Mainland China and Hong Kong. Centre for Global Higher Education Working paper no. 54, September 2020.

Yusuf, B., Walters, L.M., & Sailin, S.N. (2020). Restructuring Educational Institutions for Growth in the Fourth Industrial Revolution (the Fourth Industrial Revolution): A Systematic Review. *International Journal of Emerging Technologies in Learning*, 15(3): 93-109

Zhao, Y. (2018). The changing context of teaching and implications for teacher education. *Peabody Journal of Education*, 93(3): 295-308

Higher Education Adaptation in the Age of the Fourth Industrial Revolution

T. Kulati

Independent Consultant

tkulati@iafrica.com

Abstract

In the past couple of years, South Africa has seen a proliferation of debates on the implications of the Fourth Industrial Revolution for various public and private spheres of the economy and society that are seen to be central to its development trajectory. Higher education has generally been seen to be behind the curve and needing to 'jack up its act' in order to reap the benefits of this revolution. This paper explores the dynamics of higher education adaptation in the context of these far-reaching changes in its external environments. In particular, the paper seeks to interrogate the extent to which universities are organised (structured) and managed such that they meet the challenges of the Fourth Industrial Revolution. Through a critical appraisal of the literature on agile governance and organisation, which are seen to be the most appropriate approaches or models for navigating the advent of the Fourth Industrial Revolution, the paper explores the challenges facing higher education in the light of these developments. Drawing on some key theoretical frameworks, the paper then explores the nature of higher education organisation and management, and how the university has sought to be responsive to external demands for change and relevance.

Keywords: Fourth Industrial Revolution, agile governance, higher education management, higher education adaptation, contingency theory, networked university

Introduction

There has been a lot of discussion on the emergence of the Fourth Industrial Revolution and its implications for societal change and development. The topic has also gained currency in South Africa to such an extent that a Presidential Commission on the Fourth Industrial Revolution was established in 2019 to help government 'identify policies, strategies and plans that are needed to position South Africa as a leading country in the evolution and development of the Fourth Industrial Revolution.'[1]

The report of the Presidential Commission was released in October 2020 in the midst of the Covid-19 pandemic, something that probably led to the report not getting the attention the Presidency would have wished. There have also been other initiatives that have been established to promote dialogue on the emergence of the Fourth Industrial Revolution and its implications for South African society, most notable of which is the Fourth Industrial Revolution South Africa, which is a partnership between the Department of Communications and Digital Technologies and several organisations, which include three universities (namely the universities of Fort Hare, Johannesburg and the Witwatersrand), and blue-chip companies such as Telkom, Deloitte, Huawei and Vodacom. [2]

[1] From 'Terms of Reference for the Presidential Commission on the Fourth Industrial Revolution', Government Gazette No. 42388, 9 April 2019.

[2] Cf. https://www.4irsa.org/

The genesis of this paper is the webinar that was organised by the Council on Higher Education in September 2020, whose theme was 'Advancing the Fourth Industrial Revolution within the Context of the Transformation of Higher Education in South Africa', and in which webinar the author was a respondent to some of the presentations. The discussions in the webinar dealt mainly with issues relating to the implications of the Fourth Industrial Revolution for access (epistemological and physical) to higher education, the curriculum, and the process of teaching and learning in universities. Upon reflecting the various issues covered in the webinar, it became apparent to this author that there was very little engagement with the question of the extent to which the structure and organisation of the university either facilitates or inhibits its ability to respond to the challenges of the Fourth Industrial Revolution. While this paper is very much exploratory, it seeks to interrogate the extent to which universities are organised (structured) and managed such that they meet the challenges of the Fourth Industrial Revolution (the Fourth Industrial Revolution). As a consequence, the discussion and ideas offered are very much tentative, and will hopefully benefit from a critical appraisal from those interested in the area of higher education organisation and governance.

Literature overview and background

A useful starting point in discussing the issues central to the topic of this paper is to examine elements of the White Paper that was released in 2018 by the World Economic Forum's Centre for the Fourth Industrial Revolution, which is titled: *Agile Governance: Reimagining Policy-making in the Fourth Industrial Revolution*.[3] As the focus of the White Paper is on the implications of the Fourth Industrial Revolution for governmental public policy-making, and thus covers a wider range of issues, the discussion in this paper is limited only to those aspects of the White Paper that are of relevance to the focus of this paper.

Agile governance

According to the White Paper, a number of factors underlying the Fourth Industrial Revolution are compelling governments to reconfigure and reimagine the nature of governance and public policymaking. The combination of the interlinked dynamics and pace of technological change, the transnational character and impact of these changes, and the complex, 'transformative' and political nature of these technologies is driving the need for the transformation of traditional governance structures, and a change in approach to governance and policy-making models in the public sector (World Economic Forum, 2017). The potentially disruptive nature of these technologies to labour markets, the environment, human interactions and behaviour, and organisational strategies, requires new policies, regulatory frameworks and governance approaches. Thus, the central proposition of the White Paper is that in order for governments to not only respond to, but to proactively shape and manage how these technological changes impact society, they need to introduce or adopt 'agile governance' approaches (World Economic Forum, 2017).

The WP defines agile governance as an approach to policy-making that is adaptive, human-centred, inclusive, and sustainable, and which acknowledges that the process of policymaking is not the exclusive preserve of governments but is rather an increasingly multi-stakeholder effort. Agile governance is also described as the ability to, proactively or reactively, embrace change and learn from change, and to being continuously ready to rapidly navigate the change process (World Economic

[3] https://www.weforum.org/whitepapers/agile-governance-reimagining-policy-making-in-the-fourth-industrial-revolution

Forum, 2017). Rather than working from a script (which is the nature of a compliance-driven approach to governance) agility in governance presupposes or assumes a proactive posture with respect to the decision-making process.

In the South African public policy-making context, it is clear that the first part of the definition above, which deals with the principle of transparency and multi-stakeholder involvement in the policymaking process, is already an entrenched aspect. This is especially the case within the higher education context, whose legislative and policy framework, as contained in the Education White Paper 3 on transformation of higher education, stipulates the principles underpinning higher education governance, both at the national and institutional levels (Department of Education, 1997). The Education White Paper 3 states that 'good governance' is predicated on the recognition of the existence of stakeholders with different interests, and the 'inevitability' of contestation among these stakeholders (Department of Education, 1997: 35).

The White Paper then proceeds to frame the policy challenge facing government as the need to 'create structures and encourage processes which enable differences to be negotiated in participative and transparent ways' (Department of Education, 1997). In this regard, the legislative framework recognises that the challenges of developing a transformed higher education system cannot be achieved by government working alone but requires it to work co-operatively with higher education institutions and other civil society formations 'in a spirit of partnership and mutual dependence' (Department of Education, 1997:35). This is referred to as the cooperative governance approach in the White Paper. The principles of participation, transparency, partnership and mutual dependence thus underpin the approach to higher education governance at the systemic and institutional levels. From the citations of the Education White 3 above, it is clear that there is considerable overlap between the underlying assumptions and principles of agile governance and those of cooperative governance.

The co-operative governance framework as espoused in the Education White Paper 3 did not specify the modalities of institutional governance as there was a recognition that universities were autonomous institutions that enjoyed the right to manage their own affairs, without fear of interference or micro-management from government (Department of Education, 1997: 36). In this regard, the regulatory framework provides space for institutions, under the guidance of their councils and the institutions' executive leadership, to shape how the broad principles of cooperative governance come to be embedded in governance practices and institutional culture.

There are, of course, limits to the compact of non-interference from government with respect to institutional governance, the prime example of which are cases where institutions are found to have become dysfunctional with regard to institutional governance or management. The determination or declaration of dysfunctionality is usually preceded by the appointment of an Independent Assessor who would conduct an investigation and provide recommendations to the Minister responsible for higher education and training. Indeed, government has, in many instances, taken over the administration and governance of those universities that were deemed to have reached a state of dysfunctionality to the extent that the Minister had to appoint an Administrator to take over the functions of Council or the executive, or both.

The one feature of agile governance that is lacking in the cooperative governance framework is the sense of urgency or 'time sensitivity', which is seen as a necessary aspect of agile governance given the current context and environment that is undergoing dynamic and rapid (technological) change

(World Economic Forum, 1997: 6). The issue of urgency, or rapid adaptation, is also a constant in the writings and research on agile organisations. This is discussed next.

Agile organisations

While the literature on agile governance focused on the nature of decision or policy making in organisations, there have also been studies undertaken on agile organisations, whose emphasis is on how organisations are structured and (re-) designed in order to enhance their agility, and therefore, responsiveness. The international consulting firm, McKinsey, has been a leader in developing a body of work on organisational agility (primarily in the private sector) from which the discussion in this paper will draw. In these studies, the agile organisation is not only contrasted to, but is also seen as the antithesis of, the 'traditional' organisation. Agility is also seen as infusing organisations with dynamism, which is defined as the ability to rapidly adapt to new or unexpected challenges (McKinsey, 2017). In this regard, an agile organisation is seen as contributing new characteristics, namely velocity (speed of decision-making) and adaptability (ability to respond to unforeseen situations), to the stability that has been a feature of the traditional organisation.

Other contrasts that are made between the traditional and the agile organisation are with respect to the structure and nature of decision-making. In contrast to the siloed structure that is a feature of the traditional organisation, with its attendant hierarchical and top-down decision-making, the agile organisation is characterised by non-linear decision-making processes, and an organisational design that is team or network-based (McKinsey, 2017). It is apparent from these distinguishing features that the 'traditional' organisation described here is the classic bureaucratic organisation that has been the dominant form of the modern, 20th century, organisation.

Borrowing from the work of Morgan (1997), the metaphor that is typically used to characterise the traditional or bureaucratic form organisation is that of a machine, which derives its stability from the standardisation of tasks and the routinisation of its administration. The bureaucratic model of organisations puts emphasis on the role that structure, hierarchy, and professional authority play in modern organisations. Weber (1974) characterised bureaucracies as networks of social groups that are dedicated to the attainment of specified goals and are structured such that they maximise efficiency.

Given the central role that structure, hierarchy (or rank), and professional authority play in the organisation, the university has also been characterised as a (professional) bureaucracy (Mintzberg, 1983; Stroup, 1966). Stroup further identifies other features of the university that are consistent with Weber's conception of the professional bureaucracy: competence is the main criterion for appointments; hierarchy and rank are recognised and respected; formal rules and regulations govern how work is organised; and job security is guaranteed (in the academic domain) through the tenure system (Stroup, 1966). Mintzberg regards the university as being an essentially bureaucratic organisation because one of its key features is the standardisation of work and behaviour (Mintzberg, 1983). This standardisation of work, and especially behaviour, is achieved through an academic training and qualification regime that serves as a form of a doctrinal apprenticeship system into the ethos and value framework of the academy and its disciplines (Mintzberg, 1983). A further bureaucratic character of the university is the authority structure that is based on rank and seniority, which is a feature of both the organisation's academic and administrative domains. There are, of course, other models that have been used to describe the structure and organisation of universities. Depending on the focus of

one's analytical lens, the university has been variously described as a collegium (Middlehurst, 1993), a political system (Baldridge, 1983), a loosely coupled system (Birnbaum, 1988), and as a networked system (Dill & Sporn, 1995).

In contrast to the image of the machine that is used to characterise the traditional, bureaucratic, organisation, the metaphor often used with reference to the agile organisation is that of an organism, which derives its dynamism from being in constant interaction with its environment. The diagram below depicts the differences in organisational structure and internal design between the 'traditional' organisation (on the left) and the 'agile' organisation (on the right), as conceptualised by McKinsey (2017). As the diagram clearly shows, the traditional organisation is structured in a top-down, hierarchical manner as befits a bureaucracy, while the structure on the right purports to show the agile organisation as a 'flat' structure without hierarchy. It is clear from the text in the diagram, however, that the role played by the organisational leadership in the agile organisation (of being the chief enablers and directors of organisational action), is apparently no different to the role that leadership plays in bureaucratic organisations.

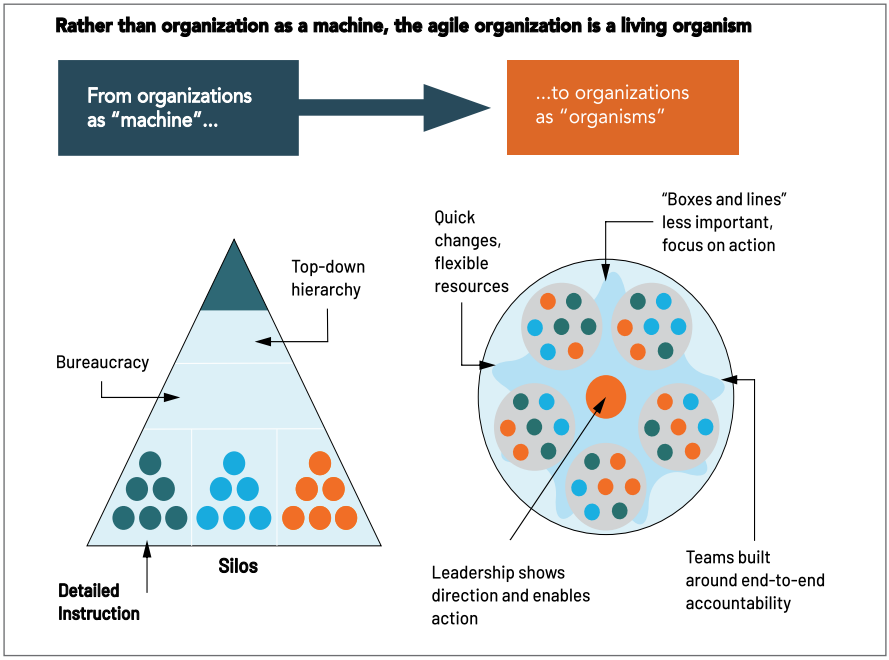

Figure 1: From organisation as machine to organisation as organism

Source: *The Five Trademarks of Agile Organisations, McKinsey (2017)*

The metaphor of the organisation as an organism originates from the systems theory (or open system theory) of organisations, where organisations are regarded as being in constant interaction with their environments in order to obtain resources that are necessary for their survival (Morgan, 1997; Scott, 1998). This constant interaction of organisations with their environments enables them to develop

survival mechanisms, which include modifications to their (internal) structure, in order for them to adapt to changes emanating from their external environment. It is therefore this character of agile organisations that provides them with flexibility and adaptiveness, thus making them akin to living organisms (Morgan, 1997). In addition to flexibility, another feature of agile organisations that derives from their design is the ability to devise rapid adaptation strategies. This is because decisions are made in and by networked teams, as opposed to having to go up the hierarchy and down again before action is taken.

While the agile organisation has been touted as the dawning of a 'new organisational paradigm' (McKinsey, 2017), this paper shows that its conceptual foundations are long established in organisation theory and will further argue that some of the features of this organisational form are emergent, if not already evident, within the university organisation. Interestingly though, a survey conducted by McKinsey shows that while agile organisations are seen as representing the new organisational paradigm, less than 10% of companies that have instituted 'agility transformations' have actually completed them successfully. [4] The discussion will now turn to an examination of the nature of the university as an organisation, and in particular the extent to which the university is organised such that it is able to respond to the challenges posed by the emergence of the Fourth Industrial Revolution.

Higher Education in the age of the Fourth Industrial Revolution

While there is a paucity of literature on the implications of the Fourth Industrial Revolution for higher education, in the limited material that has been published, there appears, nonetheless, to be some consensus that higher education is ill-suited, particularly with regard to its curriculum, to face the challenges of the Fourth Industrial Revolution (Gleason, 2018; Østergaard & Nordlund, 2019; Temmerman, 2021; Xing & Marwala, 2017). In the foreword of the only book that has been published with a focus on the implications of the Fourth Industrial Revolution for higher education, it is argued that in a context where higher education has become 'manifestly global, the operation, management, and strategy of higher education have remained staunchly parochial' (Gleason, 2018: vii). It is further stated that, because 'today's higher education was designed to meet the needs of past industrial revolutions', it has become ill-suited to meet the needs of its students as 'the Fourth Industrial Revolution world has [placed] significantly different demands on them than have previously existed' (Gleason, 2018: 5). This is a view also echoed by Østergaard & Nordlund (2019) who lament that 'two decades into the 21st Century, yet higher education is generally still geared to succeeding in the 20th Century'.

Underlying these expressions of frustration with higher education's seemingly unresponsiveness, insularity, aloofness, and general disinterestedness to the revolution unfolding around it, is a belief that, if it fails to respond to the challenges and opportunities arising from the Fourth Industrial Revolution, it will lose its relevance to society. Indeed, there is already disappointment with how higher education has responded to the emergence of the Fourth Industrial Revolution, whose response is seen as being limited if not incremental, instead of being radical and comprehensive change (Gleason, 2018). In order to be able to respond to the rapid changes in production, services and manufacturing, higher education is thus exhorted to 'change, quickly, [and] in collaboration with governments and industry' (Gleason, 218: 2).

One of the key criticisms facing universities is their seeming inability to rapidly adapt to changing

[4] McKinsey Global Survey Results: How to create an agile organisation, October 2017

circumstances, something that is a central feature of agile organisations. In particular, universities are seen as lacking in agility, a feature which, it is argued, increases the ability of an organisation to respond speedily to the challenges it faces. In an article published in *University World News* in February 2021, Temmerman argues that 2020 was a 'watershed' year for the university, in that its ability to respond to a crisis was severely tested (Temmerman, 2021). While some universities responded better than others, many were left floundering. For Temmerman, one of the distinguishing factors between those universities that managed the crisis well and those that did not is organisational agility:

> To be agile means to have the ability to move quickly and easily. It is reasonable to say that this is not a notion one naturally associates with universities. Universities are generally brilliant at lumbering along rather than doing things swiftly. It is rare indeed to see a good idea become a prompt reality. In fact, universities are full of clever people with great ideas that take forever to get implemented, if they are at all [5]

In South Africa as well, the onset of the Covid-19 pandemic has also amplified the voices questioning higher education's ability to respond to external shocks and crises. The Vice-Chancellor of the University of Cape Town, Mamokgethi Phakeng, recently opined in a radio interview that South African universities:

> are undergoing a challenge that is difficult to resist. Universities are change-averse. It is difficult to change anything at a university. There is a silver living in this [Covid-19] crisis that is forcing us to re-align education. It [has] made certain conversations unavoidable. [6]

There are some commentators, however, who see things differently, arguing that universities are being responsive to the emergence of the Fourth Industrial Revolution, transforming the way in which they are conducting their core business in order to stay relevant. According to Xing and Marwala (2017), there is a new form of university that is emerging in response to the challenges of Fourth Industrial Revolution. This university, which they refer to as 'HE 4.0', conducts teaching, research, and service in a different (interdisciplinary) manner, has virtual classrooms and laboratories, virtual libraries, and virtual teachers (Xing and Marwala, 2017). The emergence of this new form of university is seen as heralding a 'complex, dialectical and exciting opportunity' that can transform society for the better (Xing & Marwala, 2017: 10).

The authors then proceed to explore and highlight the impact of 'HE 4.0' on the mission of the university, especially as it relates to teaching, research, and service. While the authors do not explore the implications of higher education 4.0 for the organisation, governance, and management of the university *per se*, the paper does introduce, in its section on the service mission of the university, the concept of the 'University-as-a-Platform' (UaaP), which could have relevance or pointers for challenges facing university governance in the era of the Fourth Industrial Revolution (Xing & Marwala, 2017). A platform is a business model that creates value by facilitating exchanges between two or more interdependent groups, usually consumers and producers. Businesses such as Uber, Airbnb, Amazon, and eBay have been built on this model, where a platform does not own the means of producing a company's value, be it a car (Uber), a house or apartment (Airbnb), or a product item or service (Amazon, eBay, or Gumtree), but creates value through bringing together those who have a product or service to

---

[5] https://www.universityworldnews.com/post.php?story=20210208125319719

[6] https://www.702.co.za/articles/409226/there-is-never-failure-only-lessons-prof-mamokgethi-phakeng

sell, and those who require (and are prepared to pay for) those products and services. It is important to note that a platform is not a computer or mobile application or a piece of technology but, it is a 'wholistic business model' [7]. Indeed, the concept of a platform business model is not new, going back to early human civilisation. Market places (such as the modern incarnation of a flea, craft, or farmers' market), bazaars and auction houses are all examples of platform business models.

According to Xing and Marwala then, the 'University as a Platform' (UaaP) business model provides an opportunity for higher education institutions to improve their performance in meeting the needs of their primary 'customers', the students. The authors further elaborate on the features of a successful UaaP, which include (Xing & Marwala, 2017: 15):

- the delivery of inter-, multi-, and cross-disciplinary degrees;
- an appropriate blend of service models (for example, blended learning, MOOCs, and the like);
- the emergence of 'Internet of Everything' (IoE);
- the integration of routine education activities into software across a plethora of institution systems;
- up-to-date digital infrastructure; and
- enhanced connectivity among all parties residing in the higher education value chain

There has been criticism for the implications of this UaaP model for universities, especially for lecturing staff. Some unions representing academic staff have argued that one of the consequences of the shift to online learning would be the outsourcing of the teaching function to private service providers, with university lecturers relegated to being content producers.[8] In many ways, this is not a new script. Not so long ago, there was great hype and a lot of expectation that the introduction of massive open online courses (MOOCs) would increase access to university education for millions of previously unserved students across the world and herald the displacement of in-person/contact teaching and learning by these new educational innovations (Penprase, 2018). Indeed, such was the hype that the New York Times declared 2012 as the 'Year of the MOOC.' [9] However, the revolution in online learning has yet to materialise, and the access to higher education that was envisioned has yet to be realised by those at the margins of society.

Aside from a cursory statement that the platform-based business model is underpinned by 'biologically inspired thinking style', rather than 'the logic of organising', Xing and Marwala (2017) do not elaborate on what the implications of the model of the university as a platform (UaaP) are for the structuring, management, and governance of universities as organisations. This, of course, is not just a matter concerning the dynamics of organisational design, but also encompasses issues such as the kind of culture, values and organisational ethos that are embedded in this business model. While the notion of the UaaP model being inspired by biological logic (the organisation as an organism) is not developed further by Xing and Marwala, it does have resonance with the McKinsey perspective on agile organisations, as discussed earlier.

---

7 https://www.applicoinc.com/blog/what-is-a-platform-business-model

8 https://www.universityworldnews.com/post.php?story=20210214070047115

9 https://www.nytimes.com/2012/11/04/education/edlife/massive-open-online-courses-are-multiplying-at-a-rapid-pace.html

Higher Education adaptation

Contrary to the views expressed by the various commentators and practitioners in the preceding discussion, higher education institutions are not averse to innovation and adaptation. Historically, universities have had to adapt to changes to their external environments, whether these were instigated by the rise of the 'evaluative state', the emergence of new modes of production, or the spectre of the new public management (de Boer, Enders, & Leišyté, 2007; Gibbons et al, 1994; Neave, 1988). Indeed, Clark's famous study on the emergence of the 'entrepreneurial university' has shown how universities have responded in innovative ways to various challenges that they face (Clark, 1998). According to Clarke (1998), the entrepreneurial university cannot depend on the traditional organisation of university governance in order to adapt to its changing environment but requires a strengthened steering capacity that will enable the organisation to become agile, more flexible, and more focused in reacting to the (constantly changing) demands from its environments. As a consequence, the entrepreneurial university has had to reconfigure its governance and management structure so that its ability to adapt is enhanced.

There are various theories that attempt to explain how organisations adapt to changes in their external environments, which we now turn to.

Organisational adaptation

Organisational adaptation has been defined as the modifications and alterations to an organisation's structure or its component parts in order for it to adjust to changes in its external environment (Cameron, 1984). Adaptation also extends to how organisations reconfigure their relationships of engagements with elements in their environments in order to survive. Adaptation is therefore not an event, but a process whereby organisations institute interventions in order to alter how they are organised so that they respond to the challenges they face. Further, adaptation is also not confined to reactive processes or impulses, as organisations can adopt proactive or anticipatory changes. As a general proposition, however, organisations institute changes in order to respond to some discontinuity or 'lack of fit' between themselves and their environments (Cameron, 1984).

There are various theoretical perspectives that provide the analytical tools to examine and interrogate organisational change and adaptation in universities. These theoretical perspectives are part of a group of organisation theories that fall under the open systems framework. The central concern of the open systems framework is how organisations as social units come to be designed, transformed, or even resist transformation, as they interact with their environments (Morgan, 1997; Reed, 1992; Scott, 1998).

A key assumption of the framework is that organisations, just like living organisms, are 'open' to their environments and strive to strike an appropriate balance or 'fit' with their environments in order to survive. Organisations are therefore understood to be adaptive entities that are in a state of constant interaction, and a relationship of mutual interdependence, with their environments. The open systems approach distinguishes between two kinds of environments that organisations interact with (Scott, 1998). The first is the technical or task environment, which comprises of the inputs or resources that are necessary for organisational functioning and survival. The second is the institutional environment of organisations, which is constituted by the cognitive, normative and regulatory structures, activities and processes that provide stability and meaning to organisational behaviour (Scott, 1998). What

follows is a discussion of one of the key theories that seek to explain organisational adaptation, namely the contingency theory.

Contingency theory

Contingency theory focuses on the 'internal structural accommodations' that organisations have to undertake in order to cope with the pressures and demands that emanate from their environments (Reed, 1992: 80). Some of the environmental contingencies that organisations have to confront are volatile market conditions, technological change, political realignments, and resource uncertainty – and the backdrop of Covid-19 and the impact of climate change. Pandemics and natural disasters arising from environmental degradation can also be added to this list. Early studies that gave rise to contingency theory demonstrated that successful adaptation by organisations to their environments depended on the ability of those in leadership to interpret the conditions under which their organisations operated, and to devise appropriate responses to those challenges (Morgan, 1997).

An influential study that was conducted in the 1960s by Lawrence and Lorsch– who were the first to use the term 'contingency theory' insofar as it related to organisation theory - examined how organisations dealt with different kinds of contingencies, especially those related to technological change and market volatility. The main finding of the study was that differentiation and integration are the key strategies that successful organisations adopt in negotiating their environment. The more unstable, complex and demanding the environment confronted by an organisation (for example, rapid technological change), the more differentiated its organisational structures (Lawrence, 1993). In other words, an organisation with a more differentiated internal organisational structure is able to devise integrative strategies that will help it coordinate the various activities of its subunits, in order for it to be more responsive and effective. The converse of this finding is that the less complex and less prone to change an organisation's external environment, the less specialised or complex its internal structure or design. This conceptual discussion lies at the heart of the difference between the machine model and the organisation as a living organism that is depicted in the McKinsey diagram (see Figure 1) on the traditional versus the agile organisation.

The central challenge facing managers of complex organisations is how to maintain a balance between differentiation and integration (Lawrence, 1993). This challenge is, of course, particularly pertinent to complex organisations such as universities, whose organisational dynamics (for example between the administrative and academic domains) is a function of the loosely coupled nature of these organisations. The challenge of integration facing university managers relates to their ability to develop coherent organisational responses to the external demands and challenges that universities face, by striving to align the activities of the disparate academic/disciplinary units (referred to as 'academic tribes' in Becher's memorable phrase) with the strategic mission and priorities of the university (Becher, 1989). Given the lack of cohesive organisational attributes between these 'academic tribes', and their poor integrative capabilities and adherence to a common organisational vision , universities face a particular challenge in developing coordinated responses to external challenges, what Whitley has referred to as 'authoritative coordination and steering' (Whitley, 2008).

While contingency theory has made a lasting contribution to the study of complex organisations, it has been criticised for its environmental determinism, in that the organisation is regarded as a victim of forces beyond its control, lacking the capacity to chart its own course on the basis of the

strategic choices it has available or, indeed, to shape the environment itself (Reed, 1992). In other words, by regarding organisations as being at the mercy of the environment, contingency theory denudes organisations of agency or 'strategic actor-hood' (Whitley, 2008). As Morgan (1997) has noted, organisations are more than just a creation of the environment but are also socially constructed. They are products of the visions, ideas, traditions, norms, and values, and struggles of their past and present, in a way that biological organisms are not.

Notwithstanding these conceptual limitations of contingency theory, the preceding discussion has laid sufficient groundwork to consider a model of the university that explains why and how universities have managed to adapt to challenges in their external environments. Contrary to the lamentations expressed earlier by some commentators that higher education is ill-suited to deal with the challenges of the Fourth Industrial Revolution, this paper contends that a conception of the university as a networked system provides pointers to how the university will be able to engage with these challenges.

The university as a networked system

The model of the university as a networked system puts the spotlight on the interactions and relationships that the university has with its external environment, and how these interactions shape or influence the structure, governance and management of the organisation (Dill & Sporn, 1995). Universities are seen to be in a state of constant engagement with their environments as they seek resources in order to carry out their multiple mandates (of teaching, research, and service). This conception of the university has also been referred to as the 'post-modern' university (Rip, 2002). The ability to engage with, and adapt to, its external environment is regarded as one of the defining features of the networked university; it is what gives the university its dynamism and resilience.

The networked model of the university sees the organisation as being constituted of loosely coupled subunits that allows sufficient discretion for these sub-units to interact with the external environment in different ways (Weick, 1974). The loosely coupled character of the university organisation provides these (discipline-based) subunits with a high degree of autonomy to engage and forge relationships with the various elements of the university's external environment. It is this feature of the university that has enabled it to be responsive and remain relevant throughout its history and in different industrial epochs. Further, given a context of declining public funding and increased competition for resources, universities have been compelled to interact, make sense of, and transact with, their external environments. As universities have faced demands and expectations for relevance and accountability, they have had to devise innovative ways to respond to these challenges (Kulati, 2000). One of the ways in which universities have responded to these challenges has been to develop networks and collaborative partnerships with external actors such as knowledge producers (in industry, for example), government and non-governmental organisations.

The emergence of new modes and networks of knowledge production has also given rise to new organisational forms and entities within universities, which are not embedded within the traditional academic domains and structures (departments and faculties) of the university, but straddle organisational boundaries (Gibbons et al., 1994; Jacob & Hellström, 2003). In some instances, these new organisational entities are hosted in collaboration with external partners and collaborators (for example, the DST-NRF Centres of Excellence), often operating at the periphery of, and sometimes even outside, the sphere of influence and control of university managers and administrators. These

boundary spanning organisational entities have spawned complex knowledge networks and funding relationships, thereby creating considerable challenges for organisational coordination, management and leadership in universities, even while enhancing the university's adaptive capabilities (Dill & Sporn, 1995).

The model of the university as a networked system thus shifts the attention away from the central concern of the McKinsey studies with intra-organisational attributes, whether these are related to organisational structure and design, or decision-making processes. Instead, this model foregrounds issues of organisational networking, adaptation, and change, especially insofar as these have been triggered by the organisation's interaction with its environments. This, according to Rip (2002), is one of the key differentiators between the 'modern' (bureaucratic) and 'post-modern' (networked) university. The figure below provides a visual presentation of the contrast between the modern university (depicted on the left), and the networked or post-modern university (on the right).

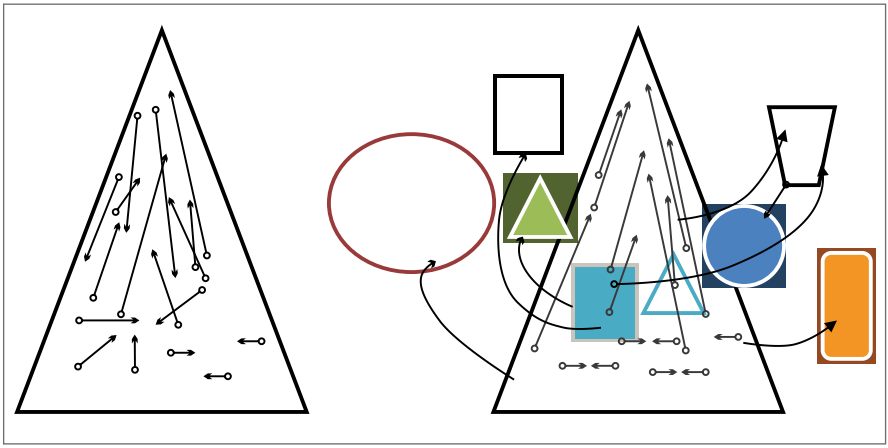

Figure 2: From the 'modern' to 'post-modern' or networked university

Source: *Rip, 2002*

To summarise, the main thrust of the model of the university as a networked system is its depiction of the university as being in a state of constant change and adaptation as it has to respond to pressures (for survival) and demands (for relevance) emanating from its external environments. In contrast to McKinsey's organisational model, which puts emphasis on internal organisational structure and design as the basis for the agile organisation's ability to be responsive, the networked university relies on the germination of relationships between organisational sub-units and the external environment for its adaptability.

Concluding observations

This paper set out to explore the extent to which universities are organised (structured) and managed such that they meet the challenges of the Fourth Industrial Revolution (the Fourth Industrial Revolution). The paper has discussed some of the ideas emerging from the literature on agile governance (from the World Economic Forum) and agile organisations (primarily from studies done by McKinsey), and

what challenges these posed for higher education institutions. It has demonstrated how some of the underlying principles of agile governance, namely stakeholder participation and transparency, are already entrenched in public policymaking in South Africa, and particularly in the regulatory framework on higher education governance. Obviously, the extent to which these principles are embedded in institutional practice and culture is an entirely different matter and lies beyond the focus of this paper.

While the literature on the implications of the Fourth Industrial Revolution is sparse, it has been noted that there are strong views expressed by some commentators on how higher education is ill-suited to meet the challenges of the Fourth Industrial Revolution. Higher education is seen as remaining 'deeply parochial' (Gleason, 2018) and ill-suited to meet the needs of the current age (Østergaard & Nordlund, 2019). Closer to home, the vice-chancellor of one of the leading universities in the country has opined that universities are generally averse to change, and that the crisis linked to the Covid-19 epidemic has 'forced' them to re-examine their approach to education. The common theme, therefore, is that higher education institutions are unable or unwilling to adapt to the challenges thrown up by this emergent industrial epoch commonly referred to as the Fourth Industrial Revolution, or to any crisis that confronts them, such as the Covid-19 pandemic.

This paper sought to demonstrate that adaptation is not anathema to higher education organisations. Borrowing from organisational theory, this paper has sought to demonstrate that organisational adaptation has been a feature of higher education change, and that universities, through their interactions and engagement with their environments, have been able to be responsive and remain relevant to the various challenges they have faced over the years. That the university has been able to adapt to external demands for change has been attributed to a key feature of its structure, the loosely coupled nature of its organisational design, which enables its subunits to undertake boundary-spanning activities by engaging in collaborative partnerships with external actors and partners.

The one missing ingredient in the university's arsenal is a rapid response capability, which is seen as a critical attribute in the Fourth Industrial Revolution. This should not be regarded as a critical shortcoming, as no one really knows what the exact impacts of the new the Fourth Industrial Revolution technologies on society will be within a given period of time (Penprase, 2018). The lag between technological innovations and their impact on productivity (the so-called productivity paradox) is attributed to the time it takes for innovation to diffuse throughout society. A dose of circumspection, and even a healthy scepticism, about the benefits of the Fourth Industrial Revolution technologies for higher education is therefore necessary, not least because it is also borne out of the experience with MOOCs, which have yet to fulfil their promise of revolutionising access to higher education.

References

Baldridge, J. V. (1983). Organisational Characteristics of Colleges and Universities. In J. V. Baldridge & T. Deal (Eds.), *The Dynamics of Organisational Change in Education*. Berkeley: McCutchan Publishing Corporation

Bargh, C., Scott, P., & Smith, D. (1996). *Governing Universities: Changing the Culture?* Buckingham: SRHE/Open University Press

Becher, T. (1989). *Academic Tribes and Territories: Intellectual Enquiry and the Culture of Disciplines.* Buckingham: SRHE/Open University Press

Birnbaum, R. (1988). *How Colleges Work: The Cybernetics of Academic Organisation and Leadership*. San Francisco: Jossey-Bass

Bleiklie, I. (1998). Justifying the Evaluative State: New Public Management Ideals in Higher Education. *European Journal of Education*, 33(3): 299–316

Braun, D., & Merrien, F.-X. (1999). Governance of Universities and Modernisation of the State: Analytical Aspects. In D. Braun & F.-X. Merrien (Eds.), *Towards a New Model of Governance for Universities? A Comparative View.* London: Jessica Kingsley Publishers

Cameron, K. S. (1984). Organisational Adaptation and Higher Education. *Journal of Higher Education,* 55(2): 122–144.

Chaffee, E. E. (1987). Organisational Concepts Underlying Governance and Administration. In M. W. Peterson & L. A. Mets (Eds.), *Key Resources on Higher Education Governance, Management, and Leadership*. San Francisco: Jossey-Bass

Clark, B. R. (1983). *The Higher Education System: Academic Organisation in Cross-National Perspective*. Berkeley, CA: University of California Press

Clark, B. R. (1995). Complexity and Differentiation: The Deepening Problem of University Integration. In D. D. Dill & B. Sporn (Eds.), *Emerging Patterns of Social Demand and University Reform:* Through a Glass Darkly. Oxford: Pergamon

Clark, B. R. (1998). *Creating Entrepreneurial Universities: Organisational Pathways of Transformation*. London: Pergamon

Cloete, N., & Kulati, T. (2003). Managerialism within a Framework of Co-Operative Governance? In A. Amaral, V. L. Meek, & I. M. Larsen (Eds.), *The Higher Education Managerial Revolution?* Dordrecht: Kluwer Academic Publishers

Cohen, M. D., & March, J. G. (1974). *Leadership and Ambiguity: The American College President*. New York: McGraw-Hill

de Boer, H.F., Enders, J. and Leišyté, L. (2007) 'Public Sector Reform in Dutch Higher Education: The Organisational Transformation of the University.' *Public Administration*, 85(27): 27-46.

Dill, D. D. (1992) 'Academic Administration,' in B. R. Clark & G. Neave (Eds.), *The Encyclopedia of Higher Education* (Vol. II, pp. 1318–1329). Oxford: Pergamon Press.

Dill, D. D., & Sporn, B. (1995). University 2001: What will the University of the Twenty-First Century look Like? In D. D. Dill & B. Sporn (Eds.), *Emerging Patterns of Social Demand and University Reform: Through a Glass Darkly*. Oxford: Pergamon

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The New Production of Knowledge*. London: Sage Publications

Gilmore, T. N., Hirschhorn, L., & Kelly, M. (1999). *Challenges of Leading and Planning in Higher Education*. CFAR

Gleason, N.W. (2018). *Higher Education in the Era of the Fourth Industrial Revolution*. Singapore: Palgrave MacMillan

Government Gazette (2019) *Terms of Reference for the Presidential Commission on the Fourth Industrial Revolution',* Government Gazette No. 42388, 9 April 2019

Hood, C. (1995). The 'New Public Management' in the 1980s: Variations on a Theme. Accounting, *Organisations and Society*, 20(2/3), 93–109

Jacob, M., & Hellström, T. (2003). Organising the Academy: New Organisational Forms and the Future of the University. *Higher Education Quarterly*, 57(1): 48–66

Kulati, T. (2000). Governance, Leadership and Institutional Change in South African Higher Education: Grappling with Instability. *Tertiary Education and Management*, 6: 177–192

Kulati, T. (2003). From Protest to Challenge: Leadership and Higher Education Change in South Africa. *Tertiary Education and Management*, 9(1): 13

Lawrence, P. R. (1993). The Contingency Approach to Organisational Design. In R. T. Golembiewski (Ed.), *Handbook of Organisational Behavior*. New York: Marcel Dekker, Inc.

Lutz, F. W. (1982). Tightening up Loose Coupling in Organisations of Higher Education. *Administrative Science Quarterly*, 27(4): 653–669

Marginson, S., & Considine, M. (2000). *The Enterprise University: Power, Governance and Reinvention in Australia*. Cambridge: Cambridge University Press

McKinsey & Company (2017) *The Five Trademarks of Agile Organisations*

Middlehurst, R. (1993). *Leading Academics*. Buckingham: SRHE/Open University Press

Miller, H. D. R. (1995). *The Management of Change in Universities: Universities, State and Economy in Australia, Canada and the United Kingdom*. Buckingham: SRHE/Open University Press

Mintzberg, H. (1983). *Structure in Fives: Designing Effective Organisations*. Englewood Cliffs, N.J.: Prentice-Hall

Morgan, G. (1997). *Images of Organisation* (2nd ed.). Newbury Park, CA.: Sage Publications

Neave, G. (1988). On the Cultivation of Quality, Efficiency and Enterprise: An Overview of Recent Trends in Higher Education in Western Europe, 1986-1988. *European Journal of Education*, 23(1–2):7–23

Østergaard, S.F. & Nordlund, A.G. (2019). The 4 Biggest Challenges to our Higher Education

Model – and what to do about them. https://www.weforum.org/agenda/2019/12/fourth-industrial-revolution-higher-education-challenges/

Penprase, B.E. (2018). The Fourth Industrial Revolution and Higher Education, in Gleason, N.W. (ed) *Higher Education in the Era of the Fourth Industrial Revolution*. Singapore: Palgrave MacMillan

Pfeffer, J., & Salancik, G. R. (1978). *The External Control of Organisations: A Resource Dependency Perspective*. New York: Harper and Row

Reed, M. I. (1992). *The Sociology of Organisations: Themes, Perspectives and Prospects*. Hempstead: Harvester Wheatsheaf

Rip, A. (2002). *Strategic Research, Post-modern Universities and Research Training*. Enschede: CHEPS/ University of Twente

Scott, W. R. (1995). *Institutions and Organisations*. Thousand Oaks, CA.: Sage Publications

Scott, W. R. (1998). *Organisations: Rational, Natural, and Open Systems*. Upper Saddle River, N.J.: Prentice-Hall

Stroup, H. (1966). *Bureaucracy in Higher Education*. New York: Free Press

Temmerman, N. (2021) 'Have universities learned how to be ready for a crisis? *University World News,* 13 February 2021. https://www.universityworldnews.com/post.php?story=20210208125319719

Van Vught, F. (1999). Innovative Universities. *Tertiary Education and Management*, 5, 347–354

Walford, G. (1987). *Restructuring Universities: Politics and Power in the Management of Change.* London: Croom Helm

Weber, M. (1974). *The Theory of Social and Economic Organisation*. New York: The Free Press

Weick, K. E. (1976). Educational Organisations as Loosely Coupled Systems. *Administrative Science Quarterly*, 21(1): 1–19.

Whitley, R. (2008). Universities as Strategic Actors: limitations and variations. In L. Engwall & D. Weaire (Eds.), *The University in the Market* (pp. 23–37). London: Portland Press

World Economic Forum (2017) *Agile Governance: Reimagining Policymaking in the Fourth Industrial Revolution.* Davos: World Economic Forum. https://www.weforum.org/whitepapers/agile-governance-reimagining-policy-making-in-the-fourth-industrial-revolution

Xing, B. & Marwala T. (2017) 'Implications of the Fourth Industrial Age for Higher Education. *The Thinker,* Vol. 73:10 - 15

The Evolution of the Contemporary Conjuncture in South Africa, and Challenges of Higher Education Transformation in the 21st Century

R. Maharajh

Institute for Economic Research on Innovation

Tshwane University of Technology

rasigan@ieri.org.za

Abstract

Humankind's advancement as a species-being has been the consequence of both evolutionary transitions and revolutionary transformations. Much of longer-term evolutionary success arises from our quest for survival and our innate curiosities. In combination with our capacity to communicate our discoveries across space and time including inter-generationally, global knowledge commons emerged through socially determined sharing and diffusion of ideas and information. The contemporary conjuncture confronting the peoples of South Africa is however characterised by widening socio-economic inequalities, political stagnation, and looming spectre of an ecological catastrophe. This paper provides an alternative narrative account of the evolutionary shaping of our contemporary conjuncture draws as a contribution to resisting and challenging the largely overdetermined technological fixation which predominates the discourse on the Fourth Industrial Revolution. By locating South Africa's 'present' at the dynamic intersection between its abhorrent past and its potentially progressive future, real opportunities could emerge for redressing the inherited negative legacies of racial capitalism and apartheid. Such potentials would also advance radical pathways that reduces inequalities, redresses the metabolic rift, and transforms the political economy.

Keywords: Political economy, science, technology, innovation, techno-economic paradigms

Background

The General Assembly of the United Nations (UN) re-admitted the Republic of South Africa as a full member-state on the 23rd of June 1994. In approving the credentials of the country, the UN also recognised the democratic breakthrough that was achieved through the relentless and heroic struggles of the vast majority of South Africans, with significant international support against an unfair and unjust apartheid regime. South Africa's first elections on the basis of a universal franchise ushered in a united, non-racial, non-sexist, and democratic constitutional democracy. The overwhelming electoral mandate for the democratically elected government of national unity was to pursue the realisation of a better life for all who live in South Africa.

Just over a quarter of a century later, the Council for Higher Education (CHE) convened a webinar on the theme of 'Advancing the Fourth Industrial Revolution within the Context of Transformation of Higher Education in South Africa'. The articulation of such a theme is ostensibly fraught with embedded assumptions and presuppositions of the various role-players and stakeholders of the post-school education and training sector. This paper is derived from a presentation at the webinar that

challenged the presumptions adopted in the framing of the theme. This paper has also benefitted from the extremely useful issues raised by the discussant to the presentation, general feedback from other participants in the webinar, and two sets of anonymous peer-review comments.

Introduction

The democratic breakthrough of 1994 afforded the people of South Africa the opportunity to confront the iniquitous political economy that had evolved through a particular profit-accumulating trajectory which spanned approximately 342 years and was marked by colonial expropriation, imperial exploitation, and racial capitalism. Racialised discrimination intertwined with epistemicide, patriarchy, religious fundamentalism, ethnic and linguistic chauvinisms to buttress the abhorrent system of apartheid[1]. According to the UN, the crime of apartheid included "denial to any members of any racial group the right to life and liberty of person: by murder of members of any racial group, by the infliction upon members of any racial group of serious bodily or mental harm, by the infringement of their freedom or dignity, or by subjecting them to torture or to cruel, inhuman or degrading treatment or punishment, and by arbitrary arrest and illegal imprisonment of members of any racial group or groups" (UN, 1973). The legacies generated through centuries of subjugation, subordination, and suppression was vast and immense. These pernicious legacies of the apartheid regime infected and corrupted all institutions in South Africa prior to 1994.

Whilst South Africans were immersed in their struggle for national liberation, the world was not disengaged. International campaigns for boycotts, disinvestments, and sanctions provided the struggle in South Africa with global solidary and resources. Representatives of the African National Congress (ANC) to the first All African Peoples' Conference in Ghana instigated a call for "an academic boycott to protest South African apartheid" in 1958 (SAHA, 2021). The UN adopted a more comprehensive set of resolutions seeking to isolate the apartheid regime and included the following encouragement to all States that had not already done so to "(t)o cease any cultural and academic collaboration with South Africa, including the exchange of scientists, students and academic personalities, as well as cooperation in research programmes" (UN, 1980). The UN's appeal was beyond just governments as it "[urged] all academic and cultural institutions to terminate all links with South Africa" (ibid.).

As Karl Marx critically observed "(t)he ideas of the ruling class are in every epoch the ruling ideas, … the class, which is the ruling material force of society, is at the same time its ruling intellectual force. The class which has the means of material production at its disposal, has control at the same time over the means of mental production, so that thereby, generally speaking, the ideas of those who lack the means of mental production are subject to it. The ruling ideas are nothing more than the ideal expression of the dominant material relationships, the dominant material relationships grasped as ideas; hence of the relationships which make the one class the ruling one, therefore, the ideas of its dominance" (Marx, 1845). Marx's work on separating idealistic outlooks from more materialistic perspectives are critically germane to this paper. The key apparatus through which 'ruling ideas' are generated, legitimised, and sometimes even venerated is the formal education and training system. The

[1] The United Nations declared that "apartheid is a crime against humanity and that inhuman acts resulting from the policies and practices of apartheid and similar policies and practices of racial segregation and discrimination… are crimes violating the principles of international law, in particular the purposes and principles of the Charter of the United Nations and constituting a serious threat to international peace and security" in 1973 (UN, 1973).

post-school system in general, and higher education institutions (such as universities) in particular, tend to occupy the apex function in mediating ideological contestation. Universities therefore play a crucial role in the battle of ideas and especially within class-based societies such as Capitalism.

The South African situation is not different from other post-yet neo-colonial capitalist regimes that govern most countries of the global South. South Africa's first university was the South African College (presently, the University of Cape Town) which was established in 1829. Nearly two centuries later, and South Africa has 26 public higher education institutions which have been designated, and differentiated into traditional-, comprehensive-, and technology-type universities. Until the collapse of the apartheid regime, the South African higher education sector consisted of racially and linguistically categorised and defined universities, technikons, and colleges.

According to Badat, there were "... 21 public universities, 15 technikons, 120 colleges of education, 24 nursing colleges, and 11 agricultural colleges" at the dawn of the post-apartheid South Africa in 1994 (Badat, 2010: 10). These institutional forms carried the imprint of racial capitalism, and apartheid, as those ideological articulations reflected the viewpoints of the ruling classes and their regimes. Hay and Monnapula-Mapesela acknowledge the racialised, linguistic, and ethnic divisions that characterised the sector, but argued further that there "... was the lack of equity in the distribution of resources to institutions, huge disparities between historically black and historically white institutions in terms of facilities and capacities, and a skewed distribution of the student population in certain disciplines, with no more than a handful of [black] students in fields such as the sciences, engineering, and technology" (Hay and Monnapula-Mapesela, 2009: 12). Thus framed, the higher education institutional landscape inherited by the first democratic post-apartheid government largely retained their characteristics as determined by the gender, race, and class contradictions of racial capitalism, and apartheid.

The government of national unity (GNU) was forged as a reconciliatory ensemble which sought to combine erstwhile oppressors and their collaborators with representatives of the national liberation movements and the mass democratic organisations of the oppressed. The GNU only lasted until the end of the first elected term in 1999. By 2020, South Africa had elected a further five governments although all six post-apartheid governments were led by the African National Congress (ANC). The transition from apartheid to democracy necessitated significant interventions aimed at transforming the economy, society, and the governance regime. With the value of hindsight, whilst much has been achieved through the de-racialisation of access to public goods and services, material and institutional inequalities persist and, in some instances, are in fact widening. The university sector has experienced a number of policy changes including four white papers, restructuring of government line-ministries, increased student enrolments, changes in the staffing, revisions to the qualifications frameworks, and budget challenges due to corruption and austerity mechanisms.

This paper challenges the predominant and overdetermined technological fixation which characterises the discourse on the Fourth Industrial Revolution, especially in the context of the real challenges confronting South Africa, its peoples, and its universities. It argues that the economic, social, and political history of the establishment of racial capitalism and apartheid renders a contemporary conjuncture riven by inequalities, spatial dislocations, and unsustainable levels of poverty, unemployment, and ecological degradation. Whereas industrial revolutions had contributed to the establishment and expansion of a wider constellation of necessary technologies and high-quality public infrastructures, racial capitalism and apartheid had ensured that these benefits accrued to only a privileged minority,

if at all. Subsequent premature deindustrialisation and the neoliberal restructuring of the economy have further eroded the potential for embracing technological change as a fulcrum towards effecting transformation and enabling a better life for all (Tregenna, 2016; amongst others).

In response to the neoliberal embrace of the inevitability of technological change and supposed leapfrogging benefits that would trickle down to all, this paper urges a much more cautious and critical engagement with the material realities experienced by the majority of South Africans in their daily struggles to survive under the capitalist regime. This paper advocates for a more deliberate decolonial stance that expressly seeks to redress epistemicide, breaks from the reproduction of an ostensibly neo-colonial knowledge production and appropriation paradigm, and responds concretely to rapid climate change. It further suggests that the disruptions emanating from both the rapid advances of new technologies in combination with accelerating climate change afford the South African higher education system significant transformative possibilities. Gazing beyond the contradictions, crises, and catastrophes of the decaying yet hegemonic capitalist mode of production offers a more robust strategic perspective for universities in South Africa to rigorously pursue an agenda of opening pathways to explore and advance a more just, equitable, and socialised future that humanity wants, needs, and is increasingly vocal in demanding.

Evolutionary Theorisation and the Political Economy

An academic discipline is established, according to Ben Martin, through a four-step process that comprises: 1) consensus-building among a group of scientists about the existence of a body of phenomena that is worthy of scientific study; 2) empirical study of the phenomena to establish a particular fact or a generalisation; 3) articulation of theories to provide a unified explanation of established empirical facts and generalizations; and 4) paradigm building to reach a consensus on the set of elements possessed in common by practitioners of a discipline such as shared commitments, shared values, and shared examples (Martin, 2008). Neo-Schumpeterian evolutionary economics has conformed to the four steps specified by Martin.

According to Esben Sloth Andersen, Joseph Schumpeter sought "to establish an economic science in the broad sense which covers economic history, statistics, economic theory, and economic sociology" (Anderson, 1993). In a seminal contribution to the literature, *The Theory of Economic Development* [1912, revised in 1934], Schumpeter established that a circular flow, excluding any innovations and innovative activities, leads to a stationary state which could be described as Walrasian equilibrium[11]. In contrast, Schumpeter introduced his concept of the entrepreneur who as the maker of "new combinations"[12] would act as the driving force for the dynamic evolution of a capitalist economy.

The concept of "creative destruction" constituted a major contribution to the literature from Schumpeter. In *Capitalism, Socialism and Democracy* (1942), Schumpeter defines the concept to denote a "process of industrial mutation that incessantly revolutionises the economic structure from within, incessantly destroying the old one, incessantly creating a new one" (Schumpeter, 1942).

[11] Leon Walrus is recognised as the originator of the general equilibrium theory.

[12] The five new combinations described by Schumpeter are: 1) production of new types of goods or change of properties of the existing goods; 2) introduction of the new method of production, that may be based on the new scientific discovery; 3) opening of a new market; 4) use of the new sources of raw materials and intermediate goods; 5) new organisation of production.

Anderson argues that Schumpeter "upheld an opening toward a more comprehensive understanding of the evolutionary process by emphasising that his analysis did not only cover process innovation and product innovation, but also organisational innovation, the opening up of new geographical regions and innovation with respect to economic inputs" (Andersen, 2010). Schumpeter can clearly be seen to have defined the role of technological and organisational innovation in driving and shaping the growth trajectory of capitalist economies (Solow, 2007).

Nelson and Winter's theory of evolutionary economic change rests on three basic conceptual devices. The first of these is the idea of an "organisational routine" (Nelson and Winter, 1982). They define an organisational routine as the ways of doing things that are organisationally framed combined with the "ways of determining what to do" (Nelson and Winter, 1982). They stress the non-static nature of their deployment of the concept in contrast to the more orthodox terminology of "capabilities" and "choices". They also advantage the reality over the normative and state that "The class of things a firm is actually doing or has recently done deserves a very different conceptual status than a hypothetical set of abstract possibilities that an external observer might conceive to be available to that firm" (Nelson and Winter, 1982).

The second major concept defined by Nelson and Winter is the notion of "search". Search describes "all those organisational activities which are associated with the evaluation of current routines, and which may lead to their modification, to more drastic change, or to their replacement" (Nelson and Winter, 1982). They propose that we recognise "search"-related activities as patterns. As patterns have a distribution characterised by random probability; the "searches" of firms offer scope for statistical analysis (Nelson and Winter, 1982). They further suggest that just as understanding genetics allows scientists to appreciate mutations; applying similar tools to the organisation of the search mechanism within firms generates a possibility to predict outputs and outcomes.

The third basic concept underpinning their theoretical work is the "selection environment". This refers to "the ensemble of considerations which affects its well-being and hence the extent to which it [the firm] expands or contracts" (Nelson and Winter, 1982). In its deployment, the selection environment internalises perceptions from outside the firm and transforms the externality into a concrete internal reality. Included in this knowledge internalisation are product demand and factor supply conditions combined with information regarding the "characteristics and behaviour of the other firms in the sector" (Nelson and Winter, 1982). They also use scale differences between genotypes and individual organisms to introduce "differential growth" as another defining feature of evolutionary economics. Nelson and Winter thereby and through their three major conceptual devices refine the understanding of the firm away from the convention of organisational form or structure into a much more elaborate co-ordinator of "routines".

The evolutionary perspective of Nelson and Winter provided analysts with the means through which the dynamics of economic growth could be understood without merely assuming the profit-maximisation function prescribed by static equilibrium models. "Diversity and pluralism" replace the rhetoric of 'social optimums' or the 'invisible hand' and encourage economic analysis to be practised in a practical and non-dogmatic spirit (Nelson and Winter, 1982). By focusing on the unit of the firm, the complexity and unevenness which lies at the core of the capitalist system on a unit scale can be appreciated. Evolution, framed in the neo-Schumpeterian context, can clearly be recognised as a process of self-transformation.

Most of the neoliberal renditions of this school of economic thought suggest that the causes of economic change can be identified with the motivation and capacity of economic agents to learn and to innovate. This provides an important contrast to the neo-classical framings and allows for the appreciation that technology is endogenous, and not exclusively, an exogenous shock. The Neo-Schumpeterian school has also tended to widen the focuses on preferences, technology, and institutions as they have often formed the objects of analysis. Evolutionary processes in the economy are assumed to follow regular patterns on which explanatory hypotheses can be based, rather than forming an erratic sequence of singular historical events.

A significant and considerable body of literature has been generated which focuses on the processes that transform the economy from within and investigates their implications for firms and industries, production, trade, employment, and growth. Consistency in the school of thought is achieved through a common assumption that processes emerge from the activities of agents with bounded rationality who learn from their own experience and that of others and who are capable of innovating. This suggests that the diversity of individual capabilities, learning efforts, and innovative activities results in growing, distributed knowledge in the economy that supports the variety of coexisting technologies, institutions, and commercial enterprises. It also posits a critical feature, variety, which drives competition and facilitates the discovery of better ways of doing things.

Evolutionary economics sees firms and the supportive knowledge infrastructures as constituting the core of its system. In principle, all firms are in the core since every firm has a potential for developing, absorbing, or using new technology. The wider setting refers to institutions that contribute to competence building and institutions that shape human interaction in relation to innovation. These also include the "family pattern, education system, career patterns in labour markets, inequality and social welfare systems; historical record of macroeconomic stability and the access to finance; final demand from households and public sector organisations; and government and public policy directly aiming at stimulating innovation, including diffusion and efficient use" (Lundvall, 2007).

Chris Freeman and a range of collaborators including Luc Soete, Francisco Louçã, and Carlota Pérez have constructed a consistent range of techno-economic paradigms to explain the transformations experienced by world systems since the advent of industrial capitalism in the mid-18th Century in western Europe. These scholars have identified at least five techno-economic paradigms (TEPs) which coincide with three major changes within the overall Capitalist Mode of Production.

Table 1: Summary of the Five Techno-Economic Paradigms

Approximate Period	Description	Key Sectors	Economic Organisation
1770s to 1840s	Early Mechanization	Textiles, Canals, Turnpike Roads	Individual entrepreneurs and small firms; local capital and individual wealth
1830s to 1890s	Steam Power and Railway	Steam Engines, Railway, World Shipping	Small firm competition, but emergence of large firms with unprecedented size; limited liability corporations and joint stock ownership

Approximate Period	Description	Key Sectors	Economic Organisation
1880s to 1940s	Electrical and Heavy Engineering	Electrical Engineering, Chemical Process Industries, Steel ships, Heavy armaments	Giant firms, cartels, trusts; mergers and acquisitions; state regulation and enforcement of anti-trust; professional management teams
1930s to 1980s	Fordist Mass Production	Automobiles, Aircraft, Consumer Durables, Synthetic Materials	Oligopolistic competition; emergence of multinational corporations; rise of foreign direct investment; vertical integration; technocratic management styles and approaches
1970s to …	Information and Communication	Computers, Software, Telecommunications, Digital Technologies	Networks of large and small firms based increasingly on computer networks; wave of entrepreneurial activity associated with new technologies; strong regional clusters of innovative and entrepreneurial firms

Source: Conceição & Heitor, 2003 [Adapted from Freeman and Soete, 1997]

Whilst this paper draws on evolutionary economics and the innovation systems literature, it essentially represents a materialist perspective determined by critical studies of the political economy of contemporary South Africa and world systems. Marx and Engels had already noted in the Communist Manifesto that "(t)he bourgeoisie itself, ..., supplies the proletariat with its own elements of political and general education, in other words, it furnishes the proletariat with weapons for fighting the bourgeoisie" (Marx and Engels, 1848). In countering the further commodification and privatisation tendencies aimed at reducing the State's role in the provision of education (albeit as a function of capitalist society), this paper is aligned with the social purpose of education and the demands for universal, free, and high-quality education and training for all [cf. Fees must Fall campaign]. This paper therefore resonates with the view that "(t)he Communists have not invented the intervention of society in education; they do but seek to alter the character of that intervention, and to rescue education from the influence of the ruling class" (Marx and Engels, 1848).

In utilising a materialist conception of history, this paper entrenches itself in the contradictions of the class struggle in South Africa and world systems. It therefore argues against the technocentric propositions of the Fourth Industrial Revolution discourse and embellishes upon the social shaping of technology within the production processes in the early 21st Century of the Common Era. The next section explicates more about the foundations, evolutionary history, and revolutionary potentials of the contemporary conjuncture.

The Evolution of our Contemporary Conjuncture

Earth, which is the shared and common home-planet of many species, has formed the backdrop to much hubris celebrating the ascent of the human species towards its apparent global domination over many, but not all, of the biodiversity that constitutes the worlds living organisms. Hegemony is usually

portrayed as the cumulative consequences of a series of evolutionary adaptations, and revolutionary leaps. In the context of long history human beings, the quest for human survival and reproductive success, has increasingly required the human species to expand its individual capabilities, albeit constrained by the social capacities to better understand the environment from wherein the human species has originated, and to share such knowledge amongst others, and across generations. The pursuit of new insights into the wider physical realms surrounding human beings in the cosmos and into quantum realms searching for exotic sub-atomic forces and matter are modern manifestations of inquisitive processes that have enabled the growth and expansion of the human species. Research, development, science, and technology have enabled the codification of knowledge and its intergenerational transmission.

The current phase of globalisation is qualitatively and quantitatively distinct from earlier incarnations. Whilst challenges of geographical dispersal of the human species have largely been redressed through mechanical technologies that physically connected human beings together through multimodal transportation, contemporary advances in information and communications technologies now converge through digital interconnectivities that bring human beings all into even tighter networks. The scientific and technological prowess of human beings continuously contribute to the shrinkage of physical distances. In the second decade of the third millennium of common era, there are human-made vehicles currently exploring interstellar space[13]. While the tactile learning by doing remains influential, the human capacities and capabilities for abstract reasoning has inevitably accelerated. The gross results of the expansion of the collective human capabilities include the increased capacity to produce the material means for human reproduction beyond survivalist requirements. Such productive competences are however neither evenly distributed nor universally accessible. Consequently, the 21st Century remains largely characterised by overproduction, underconsumption, inequitable distributional patterns, and the generation of significant waste (pollution) notwithstanding or rather maybe, including the fact that the technological artifacts are now found beyond the boundaries of the solar system.

Notwithstanding human beings' closer interconnections between each other in digital space, they remain segregated and segmented in world systems that perpetuate combined yet uneven development in the geophysical realm. Consequently, the 21st Century remains largely characterised by concurrent overproduction, underconsumption, inequitable distribution, and a significant generation of waste and pollution. World systems analysis renders a global political economy and international division of labour that remains largely characterised as combined, uneven, and yet common (Maharajh, 2015; Maharajh, 2018).

According to data from the World Bank, the United States of America (USA) contributed nearly 24.4% of the gross domestic product (GDP) of the entire planet whilst hosting only approximately 4.3% of the world's human population (World Bank, 2020). The gap between the largest economy and the next in size was about US$7 trillion between the USA and the Peoples Republic of China (US$ 21.43 and US$ 14.34 respectively). China contributed 16.34% of the world's GDP whilst being home to over 18% of the global population which maintains relative proportionality between its demographics and its economy.

[13] According to the Johns Hopkins University Applied Physics Laboratory, "... five spacecraft have escaped the Sun's gravity field to travel to the outer solar system toward interstellar space: Pioneer 10 and 11, Voyagers 1 and 2, and New Horizons" (JHU, 2021).

These two largest economies, however, dwarf the rest of the world, relegating the rest to small sizes. South Africa's contribution of only 0.4% was just below Nigeria's 0.51% and just above Egypt's 0.35% thereby constituting the most significant economies in Africa (World Bank, 2020).

In 2019, 43 countries generated over 90% of world GDP, whilst the remaining 152 countries collectively only produced 9.8% of world GDP in 2019 (World Bank, 2020). This international unevenness is further expressed in the World Bank's segregation of the countries of the world according to their per capita income levels. The World Bank deploys four income groupings determined by gross national income (GNI) per capita in U.S. dollars which are converted from local currency using the World Bank Atlas method: low ($1,035 or less in 2019), lower-middle (between $1,036 and $4,045), upper-middle (between $4,046 and $12,535), and high ($12,536 or more) to segregate the economies of the world (World Bank, 2020).

In a review of the preceding four decades of developments in the field of economics, Laurie Macfarlane states that "(a) worker in Malawi will get paid a fraction of a worker in London, even if they perform roughly the same type of labour" (Macfarlane, 2019). According to Macfarlane, such an inequitable situation is the consequence of a 'lottery of birth' or as he argues: "because the worker in London is lucky enough to be born in a powerful country with a legacy of imperialism that has rigged rules of the global economy its favour" (Macfarlane, 2019). South Africa, in the World Bank's categorisation is placed as an upper-middle income country with GNI of US$12,670 per capita in 2019 (World Bank, 2020). Whilst such a determination does not however suggest an equitable sharing of incomes within the country, it does point to the comparative international inequalities. Thus, this segregation of economies by income levels affords us the opportunity to view the indicator as a proxy for the international division of labour.

Income groupings also provides a useful correspondence with the world systems stratification of the countries of the world into three main categories and determined by trade flows: core, semi-periphery, and periphery. In this rendition, South Africa is a semi-peripheral territory. According to Chase-Dunn and Hall, defining South Africa as a semi-periphery territory implies that the country holds one or more of the following five defining features: 1) mixes both core and peripheral forms of organisation; 2) spatially located between core and peripheral regions; 3) spatially located between two or more competing core regions; 4) mediating activities linking core and peripheral areas take place; and 5) institutional features are in intermediate in form between those forms found in adjacent core and peripheral areas (Chase-Dunn and Hall, 1997).

A critical appraisal of the political economy of post-apartheid South Africa, affirms the characterisation of the country as a semi-periphery in world systems. South Africa is geographically located amongst peripheral countries that constitute the continent of Africa; yet it has many organisational and institutional forms that are often more readily found in advanced and mature core capitalist countries. The semi-periphery status of South Africa in world systems is the consequence of the historical evolution of its political economy. It is the primacy of these fundamental and particularly unequal relations of production, its contradictions, and the balance of forces in the dynamics of class struggle that have determined the contours of the superstructural institutions such as the universities of South Africa.

The territories that constitute contemporary South Africa were expropriated from the indigenous inhabitants and incorporated into an emergent circuit of mercantile capital and world systems in the

mid-17th Century (Maharajh, 2011, amongst others). The subsequent settlement and occupation by European settlers of the territories annexed by colonial metropoles based in Europe created a form of 'primitive accumulation' that would colour (sic) the trajectory of South Africa's development. Marx had argued that primitive accumulation is "nothing else than the historical process of divorcing the producer from the means of production. It appears as primitive, because it forms the prehistoric stage of capital and of the mode of production corresponding with it" (Marx, 1887).

As Marx reminds us, "(t)he capitalist system presupposes the complete separation of the labourers from all property in the means by which they can realize their labour. As soon as capitalist production is once on its own legs, it not only maintains this separation, but reproduces it on a continually extending scale. The process, therefore, that clears the way for the capitalist system, can be none other than the process which takes away from the labourer the possession of his means of production; a process that transforms, on the one hand, the social means of subsistence and of production into capital, on the other, the immediate producers into wage labourers" (Marx, 1887). Whilst the articulation of modes of production (feudal, slave, and agrarian) afforded the indigenous populations some respite until the 19th Century, proletarianisation and the violence of colonial incorporation relentlessly built upon the iniquitous primitive capital accumulation of the 17th Century and extended until the early 20th Century.

Racial capitalism was largely installed by the end of the 19th Century in South Africa. Thus framed, the enclosure and appropriation of the lands of South Africa in the face of fierce resistance would largely establish the contours of the country's economic history in terms of gender, class, and racialisation. As noted by Bill Freund: "(t)he Netherlands and Britain were great colonial powers but what is striking was their ability to correlate imperial culture, imperial dreams and the thrust for conquest, often very brutal conquest, with enabling economic actors to move in directions that promoted capitalist growth" (Freund, 2018). The essential character of South Africa's racial capitalism emerged from the expropriation of the indigenous peoples and their designation as potential wage labourers without the means to reproduce themselves.

The emergent relations of production perpetuated and reproduced the racialised designations of the white capitalist class and the black working class. Economic development of primary sectors such as agriculture, mining, and energy induced, and extended, these unequal capitalist relations of production. According to Freund, "settler capitalism, which brought to this region a version, limited as it was to be sure, of the Industrious Revolution of de Vries[14], was important in creating instruments which a purposeful developmental project, partnered and managed by the State in the twentieth century, could use before its contradictions in terms of racial exclusion created increasing problems" (Freund, 2018).

The 20th Century therefore witnessed an elaboration of a 'special type' of modernisation and industrialisation of South Africa whereby a fraction of white capital attained the levers of State control and consolidated segregation and racial capitalism into an apartheid regime in 1948. The technological infrastructure, scientific institutions, and knowledge capabilities of the population could therefore be seen to have co-evolved under colonial, racial, capitalist, and apartheid periods, and were therefore also marked by their particular periodisation whilst ostensibly retaining their essential racialised

[14] According to de Vries: "The industrious revolution was a process of household-based resource reallocation that increased both the supply of marketed commodities and labour and the demand for market-supplied goods. The industrious revolution was a household-level change with important demand side features that preceded the Industrial Revolution, a supply-side phenomenon" (de Vries, 1994).

characteristics.

Subsequent to the collapse of apartheid, the democratic South Africa has undertaken a series of processes of reform that have modified its infrastructures, institutions, and capabilities. For the purposes of the discussion in this paper, the post-apartheid reforms may be periodised into at least four distinct eras since the democratic breakthrough of 1994. The first period extends between 1994 and 1996, and this was when the Reconstruction and Development Programme (RDP) provided the overarching macro-context for seeking to transform South Africa. This period was however not continued and was truncated by the imposition of a structural adjustment scheme called the Growth, Employment and Redistribution (GEAR) between 1996 and 2005.

GEAR failed to deliver consistent and shared sustainable growth, substantive increases in employment, or transformative redistribution. As GEAR deliberately reduced government expenditures and embraced austerity in the face of rapidly escalating inequalities and uneven development, the ruling party introduced its Accelerated and Shared Growth Initiative for South Africa (ASGISA) between 2006 and 2014. This largely 'market-biased' attempt at restructuring South Africa became mired in corruption and malevolence resulting in popular mobilisation amongst civil society, capital, and labour for the development of a new development plan (NDP). The NDP was eventually introduced with much confusion and ambiguity in 2015 and was already handicapped by its neoliberal orientation. By the end of 2017, much of the NDP was unimplemented or only partially induced whilst an internal change of leadership within the ruling party resulted in the emergence of rhetoric suggesting the need for a new dawn. Since then, a raft of revised policies and strategies proliferated whilst however remaining tethered to fundamentalist and dogmatic conservative fiscal and monetary policy frameworks.

During the preceding three millennia, and most concentrated in the last five decades of the 20th Century, environmental degradation, atmospheric emissions, and water pollution have accumulated, and the planet is now witness to an accelerating mass extinction of biodiversity, global warming, and climate change[15]. Whilst the complex interaction within biomes has over the long-term generated immense systemic variations, and helped configure socio-cultural distinctions, the current trajectory and its resource-intensity is proving to be almost self-endangering. Exacerbating uncertainty is the recognition that the world's weather patterns have been radically altered making abrupt climate change unpredictable though inevitable. The human species is therefore confronted by a crisis of existence and conditions of increased precarity.

Climate change remains of critical importance as it affects all life on Earth. International efforts such as regular gatherings of the political units constituting the United Nations have generated a range of global agreements which further define the boundary conditionalities under which the nation-state sovereignties have been constrained. The seventeen Sustainable Development Goals (SDGs) are indicative of the concerted and cooperative actions required for humanity to possibly rescue itself from an inevitable ecological catastrophe. As part of this new arrangement, nationally determined contributions from member states of the UN have established thresholds on greenhouse gas emission. Climate-resilient development demands much more attention and could potentially benefit from the excellent work of Rockström, Steffen, Noone *et al*. who defined planetary boundaries as a means "for

[15] "Climate change" means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. (Article 1(2) UN Framework Convention on Climate Change).

estimating a safe operating space for humanity with respect to the functioning of the Earth System" (Rockström *et al*., 2009).

At a continental level, all of the ecological challenges are heightened due largely to the combined and uneven development processes that have disabled Africa. A continent of approximately 1.4 billion people has to consistently endure the ravages of rapid climate change whilst simultaneously remaining chained to the segmentation and segregation of Africa since the Berlin Conference of 1884 - 1885. Imperial ambitions and primitive accumulation by the metropoles of colonial expansion ensured that the continent's insertion into world systems was on the basis of unfair, iniquitous, and disadvantageous terms. At the end of 2020, the African Continental Free Trade Area came into force. This holds the potential of either radically changing the continent's social, economic, and political trajectories towards an ecologically sustainable paradigm or further consolidating Africa's fragmentation, exclusion, and marginalisation on world systems.

The emergence and global transmission of a severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus that caused the coronavirus disease 2019 (COVID-19) pandemic in 2020 has however revealed many of the weaknesses and accentuated the contradictions of our contemporary conjuncture. As noted in an editorial penned by the Locust Arts and Letters Collective, "(i)n March came the plague, Covid-19. By the time you read this, the pandemic and the economic crisis it triggered and exacerbated (but did not cause), will have raged for months. We find ourselves in a new terrain, a new world -- but one fundamentally the product of the world that existed before. … With capital determined to maintain, if not accelerate, rates of surplus value extraction – in contradiction to needed public health policies -- the conflict between use and exchange value was demystified for countless workers" (Editor, 2020).

According to the Johns Hopkins Coronavirus Resource Centre,[16] approximately 237,956,055 people were infected by SARS-CoV-2, and it was further estimated that 4,853,836 people died due to the COVID-19 pandemic as of 11 October 2021. Science, technology, and innovation were mobilised and utilised in rapidly generating therapeutic responses to the virus. According to Médecins Sans Frontières (MSF) the rapid development and production of many vaccines have tended to mimic the global maldistribution of power as reflected in world systems. The international political economy has afforded transnational pharmaceutical corporations to steer their 'respective' governments in the global North to seek and defend their profitability rather than save lives, thereby constituting a virulent (sic) vaccine apartheid.

Core capitalist countries purchased many more doses of the limited stock of vaccines than what was required for their respective populations, whilst resisting progressive proposals for the waiver of intellectual property rights regimes to allow for wider and swifter production and distribution. The resulting precarity of people in the global South reminds us about the critical importance of recognising the power dynamics underpinning the contemporary political economy of global neoliberal capitalism. The COVID-19 pandemic has laid bare the problems of global inequities and the maldistribution of capacities, capabilities, and competences whilst also highlighting the social basis for contemporary conjuncture. It is therefore imperative that the relationship between research and development, science, technology, knowledge, innovation, industry, and education be thoroughly rethought and

[16] The live database is presented as a dashboard of statistics and is accessible via https://coronavirus.jhu.edu/map.html

reconsidered.

Conclusions

South Africa's pasts, present, and future prospects converge in shaping, and defining the country's contemporary conjuncture. The nearly universal abhorrence of the country's history of racial capitalism and apartheid combines with escalating disquiet about the present situation and increasing scepticism about the future serve to render extreme pessimism. Whereas significant opportunities emerge from the relentless advance of science, technology, and innovation, South Africa remains heavily burdened by the global legacies of colonial epistemicide, centuries of racial capitalism, and an acute five decades of apartheid. The peoples of southern Africa endured the vicious onslaught against their very recognition as human beings, whilst heroically resisting the violence of subordinations subjugations, and suppressions.

The democratic breakthrough of 1994 unleashed the possibilities of reconstructing and developing the country through redistribution and the co-construction of a united, non-racial, non-sexist, and fully enfranchised country orientated towards the provision of a better life for all. The potential for ensuring inclusivity, decoloniality, endogeneity, resilience, and sustainability for South Africa lies within the context of the global knowledge commons whereby collective public goods are purposefully co-constructed rather than in seeking further commodification for the purposes of appropriation, and the continued accumulation of profits for the capitalist class. Progressive transformation therefore demands that an appropriate, relevant, and decolonised institutional architecture be reconfigured so as to facilitate the opening of pathways towards the realisation of a better life for all rather than to just reproducing and extending the current political economy, and its inequitable relations of production, into the future.

References

Andersen, E.S. (1993) Review of R. Svedberg's Schumpeter: A Biography. *Journal of Economic Literature* 31: 1969-1970

Badat, S. (2010). *The Challenges of Transformation in Higher Education and Training Institutions in South Africa*. Midrand: Development Bank of Southern Africa

Chase-Dunn, C., & Hall, T.D. (1997). *Rise and Demise: Comparing World-Systems*. Boulder: Westview Press.

Conceição, P. & Heitor, M.V. (2003). Techno-economic Paradigms and Latecomer Industrialization, UNESCO Encyclopaedia of Life Support Systems. Accessed at https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.540.2273&rep=rep1&type=pdf

De Vries, J. (1994). The Industrial Revolution and the Industrious Revolution. *Journal of Economic History* 54(2): 249-270

Denning, S. (2017). From a Casino Economy to a New Golden Age: Carlota Pérez at Drucker Forum 2017, Forbes, 25 November. Accessed at: https://www.forbes.com/sites/stevedenning/2017/11/25/from-a-casino-economy-to-a-new-golden-age-carlota-perez-at-drucker-forum-2017/#6a9e89813b4e

Editorial. (2020). Labour Under an Alien Sky. *The Locust Review, The Locust Arts + Letters Collective,* 20 August.

Fine, B., & Rustomjee, Z. (1996). *The Political Economy of South Africa: From Minerals-Energy Complex to Industrialisation*. London: Hurst

Freeman, C. (1991). Innovation, Changes of Techno-Economic Paradigm and Biological Analogies in Economics. *Revue économique* 42 (2): 211-232

Freeman, C., & Louçã, F. (2001). *As Time Goes By: From the Industrial Revolutions to the Information Revolution*. London: Oxford University Press

Freeman, C., Clark, J., & Soete, L. (1982). *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*. Westport: Greenwood Press

Freund, B. (2019). *Twentieth-Century South Africa: A Developmental History*. New York: Cambridge University Press

Hall, S., & Massey, D. (2010). Interpreting the Crisis. *Soundings* 44 (Spring): 57-71

Hay, D., & Monnapula-Mapesela, M. (2009) South African Education Before and After 1994: A Policy Perspective. in Blitzer E (ed.) *Higher Education in South Africa*. Stellenbosch: Sun Press

Kondratiev, N.D. (1925). *The Static and Dynamic Views of Economics*. Quarterly Journal of Economics 39: 575-583

Kondratiev, N.D. (1998). *The Complete Works of Nikolai D. Kondratiev*. (Edited by W. Samuels and N. Makasheva), London: Pickering and Chatto

Magubane, B. (1979). *The Political Economy of Race and Class in South Africa*. New York: Monthly

Review Press.

Macfarlane, L. (2019). New Economics are the Method: The Goal is to Change the World. *New Economics Zine*, Issue 1, Autumn: 6-7

Maharajh, R. (2008). Global Economic Policy Reform. Chapter 9, in Pressend, Michelle and Michelle Ruiters [editors] *Dilemmas of Poverty and Development: A Proposed Policy Framework for the Southern African Development Community*. Midrand: Institute for Global Dialogue

Maharajh, R. (2011). Innovating beyond Racial Capitalism: A Contribution towards the Analysis of the Political Economy of Post-Apartheid South Africa. *Lund Studies in Research Policy 3*. Lund: Lund University Press

Maharajh, R. (2015). The Metabolic Rift, Anachronistic Institutions, and the Anthropocene. *SPANDA Journal* 6 (1): 1-10

Maharajh, R. (2016). Racial Capitalism, Apartheid and the Negotiated Post-Apartheid Constitutional Democracy. Chapter 7 in Mario Scerri [editor] *The Emergence of Systems of Innovation in South(ern) Africa: Long Histories and Contemporary Debates*. Johannesburg: New African Publishers

Maharajh, R. (2018). Africa and the Fourth Industrial Revolution: The Need for 'Creative Destruction' Beyond Technological Change. *Perspectives Africa 3* (December): 30-34

Maharajh, R. (2021). Long-run Global Perspectives on Evolution, Revolution, and Innovation in South Africa's Development. In Ngwane, T., & Tshoaedi, M. [editors]. *The Fourth Industrial Revolution: A Sociological Critique*. Johannesburg: Jacana Press

Maharajh, R., Motala, E.M., & Scerri, M. (2011). Post-apartheid Higher Education and the System of Innovation: Enduring Challenges. Chapter 10 in Göransson, Bo & Claes Brundenius [editors] *Universities in Transition - the Changing Role and Challenges for Academic Institutions*. New York: Springer

Marx, K. (1887). *Capital: A Critique of Political Economy*, *Volume 1*. Moscow: Progress Publishers [1984 Edition]

Marx, K., & Engels, F. (1845). *The German Ideology*. London: Lawrence & Wishart [1982 Edition]

Marx, K., & Engels, F. (1848). *The Communist Manifesto*. London: Verso [1998 edition]

Moore, J.W. (2016). *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*. Oakland: PM Press

Petralia, S. (2020). GPTs and Growth: Evidence on the Technological Adoption of Electrical and Electronic Technologies in the 1920s. *Papers in Evolutionary Economic Geography #* 20.33, Utrecht University

Rockström, J., Steffen, W., Noone, K., *et al*. (2009) A safe operating space for humanity. *Nature* 46: 472 – 475

RSA. (2019). *White Paper on Science and Technology*. Department of Science and Technology, Tshwane

SAHA. (2021): South Africa's Academic and Cultural Boycott, in South African History Archives.

Accessed at https://www.sahistory.org.za/article/south-africas-academic-and-cultural-boycott

Scerri, M. [editor]. (2018). *The Emergence of Systems of Innovation in South(ern) Africa: Long Histories and Contemporary Debates*. Johannesburg: New African Publishers

Schumpeter, J.A. (1939). *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*. New York: McGraw-Hill

Schumpeter, J.A. (1942). *Capitalism, Socialism, and Democracy*. London: Unwin University Books

Solow, R.M. (2007) Heavy Thinker: Review of Thomas K. McCraw's 'Prophet of Innovation: Joseph Schumpeter and Creative Destruction,' The New Republic. Accessed at http://www.tnr.com/article/heavy-thinker

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The Trajectory of the Anthropocene: The Great Acceleration. *The Anthropocene Review* 2(1): 81-98.

Tregenna, F. (2016). Deindustrialization and Premature Deindustrialization. Chapter 38 in *Handbook of Alternative Theories of Economic Development*. London: Elgar

UN. (1973). *International Convention on the Suppression and Punishment of the Crime of Apartheid, General Assembly Resolution* 3068(XXVIII). New York: United Nations

UN. (1980). Resolutions Adopted without reference to a Main Committee, 98th Plenary Meeting. New York: United Nations

UN. (2018). *Global Warming of 1.5 °C, Intergovernmental Panel on Climate Change*. Geneva: United Nations

Wallerstein, I. (1974). The Rise and Future Demise of the World Capitalist System: Concepts for Comparative Analysis. *Comparative Studies in Society and History* 16(4): 387-415

WEF. (2015). *Deep Shift: Technology Tipping Points and Societal Impact, Global Agenda Council on the Future of Software and Society Survey Report*. September, Davos: World Economic Forum

The Fourth Industrial Revolution: Why it Cannot Deliver Digital Transformation to South Africa

Alison Gillwald

Research ICT Africa

agillwald@researchictafrica.net

Abstract

This paper argues that the knowledge system in South Africa has failed to provide the necessary research and education to inform national public policy and the global governance of digital public goods. This has made South Africa susceptible to 'blueprints' promoted by powerful epistemic communities with vested interests, such as those of the World Economic Forum (WEF), on what it has termed 'the Fourth Industrial Revolution'. This paper is based on a reflexive process that draws on the emersion of the author over two decades in national digital and global processes of global governance and in efforts to institutionalise digital policy research and capacity building within South African universities. This experience drawing on academic and non-academic policy research by the author is used to explain the uncritical adoption of the World Economic Forum's conceptualisation of the Fourth Industrial Revolution by the South African Government for its digital transformation agenda. Empirically, it draws on the findings of the *Digital Futures* report which the author was commissioned to prepare for the National Planning Commission (NPC) to assesses South Africa's readiness for the Fourth Industrial Revolution.

Keywords: Digital transformation, Fourth Industrial Revolution, digital futures, digital inequality, digital policy research

Introduction

Arguably there has not been a more successful lobby in recent history than the World Economic Forum's Fourth Industrial Revolution. In the five short years since the launch in 2016 of Klaus Schwab's publication, *The Fourth Industrial Revolution*, at the annual meeting of business and political leaders at the World Economic Forum (WEF) in Davos, the Fourth Industrial Revolution has become global policy conventional wisdom and 'best practice'. In Schwab's own words:

> Since the concept of the Fourth Industrial Revolution became common parlance in 2016, it has caught the attention of political leaders around the world and become an essential point of discussion in the fields of economic development and international relations (Schwab, 2018a: 2).

However, there has been very little critical academic and policy discussion [17] on the World Economic

[17] Of course, there has been some critical research with is referenced in literature review below (cf. Avis, J 2018; Boyd and Holton 2018) and more popular critiques in South Africa (cf. Gillwald, 2019 & Badat, 2020), but at an international level and in terms of national policy in South Africa, the 4IR discourse is widely and largely uncritically accepted. At the time of going to press other critiques were emerging such as Trauth-Goik, identified above, and in South Africa (Moll, 2021), argues there is no basis for the claim of a 4IR, but rather he makes the case for it being viewed an ideology of globalisation promoting a particular set of norms, value and interests.

Forum's conceptualisation of the Fourth Industrial Revolution. Universities across the globe, multilateral agencies, governments, the media, international industry conferences and inevitably the public, have been swept up in the futurist vision of the Fourth Industrial Revolution in which the physical and technical realms are fused to achieve unprecedent productivity and efficiency – and the dire fate of nations who fail to embrace these inevitable technological developments in the manner proposed[18]. As a result international donor agencies and governments are diverting public funding from pro-poor policy research agendas on digital inclusion to artificial intelligence, the future of work and other W Economic Forum's Fourth Industrial Revolution agendas[19].

Perhaps it is not surprising then that South Africa defaulted into the Fourth Industrial Revolution thinking following on the World Economic Forum, as it powered on up the echelons of global governance. In 2021 it cemented a partnership framework for the United Nation's Sustainable Development Agenda 2030 bringing corporate partners, money, and expertise on climate change and the Fourth Industrial Revolution to the table, in what political scientist Ivan Wecke, (2021, np) describes as "…corporate takeover of global governance".

Following its adoption by the African National Congress at its 54th National Congress in 2018 the Fourth Industrial Revolution has become a touchstone in government strategy from economic growth to job creation and the empowerment of women and youth and innovation. In his inaugural address, President Cyril Ramaphosa said:

> Africa is poised once again to rise, to assume its place among the free and equal nations of the world. We must use that innovative talent that originated in Africa to embrace and use the Fourth Industrial Revolution to develop Africa and create jobs for the youth and empower the women of our continent[20].

The proposed vehicle for catalysing the Fourth Industrial Revolution in South Africa is a Presidential Commission on the Fourth Industrial Revolution, which President Ramaphosa announced in his first State of the Nation Address. The Commission, he noted, would "…serve as a national overarching advisory mechanism on digital transformation…" that would "…identify and recommend policies, strategies and plans that will position South Africa as a global competitive player within the digital revolution space".[21] Digital transformation may refer very narrowly to technological disruption and change as it does within World Economic Forum, but if transformation does refer to fundamental social

---

[18] Alexander Trauth-Goik, (2021) identifies a multitude of think tanks and consultancies (Deloitte, WEF, McKinsey and Company), national (Made In China, Japan Revitalization Strategy, Accelerating US Advanced Manufacturing) and intergovernmental (European Commission, 2013) strategies to demonstrate how this vision has come to dominate global discussions at both the government and corporate level in recent years.

[19] The Canadian IDRC, the Swedish International Development Agency, SIDA who have traditionally supported ICT4Development, the collection of missing national data on digital inclusion and digital inequality no longer have these programmes which have replaced by well-funded programmes on AI, Future of Work, and support for new global forums on AI governance.

[20] Ramaphosa, C. (2018) IN FULL | Read Cyril Ramaphosa's first state of the nation address. Timeslive. Available at: https://www.timeslive.co.za/politics/2018-02-16-in-full--read-cyril-ramaphosas-first-state-of-the-nation-address/

[21] South African Government. (2019). President Cyril Ramaphosa State of the Nation 2019. SA Government. Pretoria. Available at: https://www.gov.za/speeches/president-cyril-ramaphosa-2019-state-nation-address-7-feb-2019-0000

and economic change, not just technological transition, as it does in the Preamble to the Constitution of South Africa and the National Development Plan (Government of South Africa, 2012), then this paper argues that the conflation of the Fourth Industrial Revolution with digital transformation is erroneous.

The dire implications of this diversion of policy attention and resources from national 'Third Industrial Revolution' developmental priorities to the global Fourth Industrial Revolution agenda have been thrown into stark relief by the Covid-19 pandemic and associated lockdowns. Only a small elite have been able to mitigate the negative effects of the pandemic through the digital substitution of their work, schooling, and banking, and for food security. For the significant numbers of South Africans concentrated in rural areas, townships and informal settlements without access to online services, the lockdowns have resulted in the rupture of informal value chains, disruption of schooling and access to feeding schemes, inability to receive social security pay-outs or to apply for Covid-19 relief[22]. Despite the Fourth Industrial Revolution rhetoric of digital transformation[23] and the use of advanced technologies of artificial intelligence and machine learning for contact tracing and data dashboard to manage the global health crisis in mature economies, there has been almost no deployment of these technologies at scale in Africa, even South Africa, because of the levels of Internet and smart phone penetration and intensity of use and data generation have not reached the critical mass to make them viable solutions.

Meanwhile the behind-the-scenes rapid response digital research required by government to deal with the pandemic has come from one or two consultancies or think tank outside of the university system. From the digital indicators needed to establish the feasibility of Bluetooth and smartphone contact tracing, to the data policy required to safeguard the data derived from mass surveillance of the population and the assessment of temporary spectrum assignments and mandatory price reductions, the research has been undertaken by donor funded non-profit organisations[24]. Universities simply to not have established multidisciplinary policy research programmes, as demonstrated below, to respond with existing research to move swiftly enough to support public health digital initiatives to mitigate the effects of the pandemic.

---

[22] Check https//: researchictafrica.net website for forthcoming RIA COVID-19 telephone survey on digital substitution.

[23] In their book COVID-19: The Great Reset Schwab and Thierry Malleret present a critique of neoliberalism, offering instead the concept of "stakeholder capitalism". The few academic assessments beyond that by conspiracy theorists of the left and right (Rectenwald, 2021) argue however that this perpetuates the neoliberal agenda and indeed, consolidates the interests of big capital and big tech in collusion with big governments. (See for example (Trauth-Goik, 2021; (Ivan Wecke, 2021).

Through a discourse analysis Trauth-Goik contends that the appropriation of the language of social justice and just transition masks the mantle of responsibility for managing the development of new technologies being handed to business and industry. "In this way, the socio-technical imaginary of the 4th IR functions to reaffirm the dominant ideological position of neoliberalism and secure its prerogatives into an uncertain and disruptive future landscape." (Trauth-Goik, 2021)

[24] See series of blog, policy briefs and submissions from Research ICT Africa (https://www.researchictafrica.net) of which the author is executive director, based on grant funded research on these issues, some of which reflect consultations with the South African Presidency and various task teams, the National Planning Commission, the Department of Justice and expert submissions to the Competition Commission and the Independent Communications Authority of South Africa.

With this introduction on the World Economic Forum and its conception of a Fourth Industrial Revolution and South Africa's adoption of it as its national digital transformation strategy, the next section identifies the underlying problems with which this paper is concerned followed by an explanation of the approach and method adopted. From there the paper unfolds in four parts. In the first it identifies the mission of the World Economic Forum to shape global governance and national policy seeking to expose the interests behind its claims to be serving humanity. The second part undertakes a critical review of the limited academic policy literature on the Fourth Industrial Revolution, juxtaposing this with alternative policy literature that it contends could yield the framework for a transformative digital vision for the country and the kind of knowledge system. In the third part it examines the lack of development of digital policy and governance as a recognised and cutting-edge area of multidisciplinary research and education in South African universities, as it has been the case in the global North[25]. The fourth part then develops the case for the central claim of the article that South Africa has uncritically adopted the World Economic Forum's approach to the Fourth Industrial Revolution, and how in overriding the more comprehensive digital development strategies, the National Development Plan and strategies to operationalise it such as the national broadband plan South Africa Connect, threatens real digital transformation. The paper concludes with some recommendations for how to address the deficits in the knowledge system to better place the country to deal with the national global challenges arising from rapid digitalisation and datafication.

Problem statement

There are four interrelated problem areas with which this paper is concerned. The first relates to the lack of institutionalisation of digital policy research and capacity building within the South African knowledge system. The second problem area relates to implications of this for the development of a local, independent evidence and intellectual base to support the formulation of digital policy and governance that serves the public interest and national development imperatives of the country. Instead of creating a virtuous cycle of knowledge generation between the State's need for local research for evidence-based policy and the development of policy research capacity in emerging areas of digital regulation and governance, the government has over many years, with one or two exceptions, relied on consultants based outside the country, with their reports seldom made public for engagement or scrutiny[26]. The third problem arising from the second is that without such policy resources countries are unable to mount a defence against powerful epistemic communities such as the World Economic Forum, who are openly committed to 'shaping global and local policy' outcomes (Transnational Institute,

[25] Most of the 'Ivy League' and first tier research universities and leading schools of government and International Relations in the United States and the United Kingdom have dedicated centres for digital policy, internet and AI governance, see CTI, Columbia University; Berkman Klein Centre, Harvard University; Stanford Cyber Policy Centre; Oxford Internet Institute; the Alan Turing Institute at Oxford; Digital Pathways programme at the Blavatnik School of Governance and the Just AI Institute, London School of Economics, to name but a few.

[26] There are countless examples over the years in every major sector policy and licensing process documented in the five-year Presidential Reviews of Government, several of which the author contributed to. See (Gillwald A, 2020) for the most recent example of decisions taken, contrary to the outcomes of public processes such as that undertaken for South Africa's Broadband Plan and Policy, and that have been justified on the basis of various undisclosed reports in relation to the Wireless Open Access Network.

2016). The World Economic Forum's Fourth Industrial Revolution 'blueprint' [27]– produced by a body that has the resources to convene the most powerful global epistemic community in the world annually to build consensus between the private and public sector on what the future of the world should look like[28] - fills a vacuum for many countries that have not invested in what they want their own digital futures to look like. When national plans and policy are not owned, not implemented or unsuccessful and fail to provide a vision, a powerfully promoted, ready-made vision is offered by the World Economic Forum.

The fourth problem relates to the World Economic Forum's Fourth Industrial Revolution approach itself and the implications for creating conditions that prevent the country from dealing with arguably one of the wickedest policy problems that confront South Africa. The UN Secretary General, Antonio Guterres, has described digitalisation as one of two seismic shifts that will shape the 21st century, the other being the climate crisis (Guterres, 2020). Both could widen inequalities even further unless urgently addressed on a planetary scale, he contends.

At the heart of this uneven advancement of technological development is the 'digital inequality paradox' – as more people are connected to, or become data subjects of advanced technologies, the more inequality increases. Digital inequality does not only exist between those online and offline as it did with voice services (Fink & Kenny, 2003; Gunkel, 2003), but the widening inequality gap is also between those who have the technical and financial resources to use the new digital technology optimally and those who cannot afford consistent, meaningful usage or lack basic digital literacy to use new applications and services or protect their rights as data subjects (Gillwald, 2020a).

Research objective and research questions

In this context, the paper asks how the extreme digital inequality that exists in South Africa today can be ameliorated and prevented to exacerbate by the unfettered adoption of policy blueprints that are formulated for very different conditions and interests and optimised on grounds of market efficiency and productivity alone.

The hypothesis for this paper is that South Africa finds itself in a position of intellectual servitude because the State has not publicly invested in research, education and training in the area of digital policy and governance over the past two decades. Initially the lack of investment was in sectoral and competition regulation but with the dynamic evolution of the sector, subsequently in internet and data governance. The default into the readily available World Economic Forum blueprints represent just the latest example of the absence of a local evidence base for policy formulation.

---

[27] This can be seen as a series of evolving policy papers found on the WEF website but starting with Klaus Schwab's book of that name. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

[28] See Transnational Institute analysis of WEF's 's Board and who attends its meetings to see who they represent, their economic interests and political beliefs in order to understand what the future of global governance might look like. The WEF's mission is to "improve the state of the world" and to "shape global, regional and industry agendas". The study was conducted in 2016 when the theme of the meeting was the 4IR. Despite the WEF's claims that it is "accountable to all parts of society" its own statistics of attendance at Davos in 2015 show that it is highly dominated by men (83%), mainly from Europe and the US (75%). Its board at that time was overwhelming made up of men from Northern Hemisphere universities, particularly Harvard, and of a "conservative ideological persuasion." Meanwhile its year-round membership is made up exclusively of 1000 of the world's biggest multinational corporations, most with more than US$5 billion in turnover.

The following research questions arise from this:

- Why has South Africa with such strong constitutional and administrative justice imperatives defaulted into such less fit for purpose models of digital transformation?
- What frameworks would allow for the intensifying processes of digitalisation and datafication and their associated advanced technologies (artificial intelligence, machine learning, blockchain) be harnessed to produce a more even distribution of opportunities both between and within countries? And how can the risks associated with the deployment of the Fourth Industrial Revolution technologies be mitigated by South Africa for its citizens?
- Perhaps most importantly, how can South Africa build the intellectual capacity to drive a more progressive research and policy agenda for digital transformation that will challenge the unfettered adoption of new technologies and systems that are optimised on grounds of efficiency and productivity alone?

Approach

This paper adopts a reflective process that draws on the emersion of the author over two decades in national digital and global processes of global governance and in efforts to institutionalise digital policy research and capacity building within South African universities. This is not so much a matter of disclosure but conscious decision about the role of the researcher as a "provider of new conceptual models and ideas that provide means for reflective dialogue in a specific research setting or society in general" as Vaara & Kakkuri-Knuuttila (1999:17) explain. As they also argue the interpretative or constructivist processes of the researcher in adopting this reflective paradigm are not only acknowledged therefore, but, if conducted in a self-reflective way, can enhance the research process.

The development of this case is an amalgamation of several other case studies on South Africa in relation to digital policy development that are cited throughout the paper. Yin (as cited in Tellis, 1997:3) describes a case study as an empirical enquiry that investigates a contemporary phenomenon (telecoms reform) within its real life context (the political economy of South Africa), especially when as Merriam (1998:27) points out, the boundaries between the phenomena and context are not clearly evident. It is "particularistic, comprehensive and heuristic, explaining the reasons for problems and evaluating alternatives in order to enhance its applicability" (Merriam, 1998:29).

The reflective method used for the development of these embedded cases and this one, rather than assuming universal/constant relevance, explains only what needs to be explained. This selective attention to the topic goes along with an emphasis on a 'contingency constellation of factors' not because of a few fundamental effects acting independently. This requires a shift to seeing cases as engaged in a perpetual dialogue with their environment, a dialogue of action and constraint that is called a 'plot' (Abott, 1994:65). This does not mean that this approach is not analytical. Indeed, the rationale of this approach is that through analysis, a strategic argument is developed for the case. The case introduces crucial steps in the introduction of the policy under examination and "the sequence of major turning points and set of situational consequences flowing from those events" (Abott, 1994:64-65).

For the purposes of developing this case the literature review is also used as a critical analytical instrument that fulfils two purposes. It is used to support one of the central claims of the paper - that the World Economic Forum's concept of the Fourth Industrial Revolution has become conventional

wisdom as a result of an impressively orchestrated campaign to buttress capitalism under crisis over the past decade and which has allowed it to successfully influence global governance on the wicked policy challenges faced today produced by advanced capitalism (Sassen, 2013; Piketty, 2014). It is also used to offer an alternative conceptualisation of the policy challenges of digitalisation and datafication to that offered by the World Economic Forum on the Fourth Industrial Revolution.

Empirically, it consolidates the quantitative and qualitative policy research undertaken by the author for academic purposes and purposes of policy practice which tracks the evolution of digital policy from its inception in 1995. Specifically, to develop this case, the paper draws the findings of the report which the author was commissioned to prepare for the National Planning Commission (NPC) to assesses South Africa's readiness for the Fourth Industrial Revolution. Based on extensive high-level interviews with senior government officials (listed in the Digital Futures report) and desk research, this is used to demonstrate the degree to which the World Economic Forum approach is uncritically adopted throughout government and ultimately in the report of the Presidential Commission on the Fourth Industrial Revolution.

Literature review

Definitions and framing of the Fourth Industrial Revolution within the literature determine the kind and nature of policy issues that arise for consideration. From the technological determinist viewpoint of the dominant Fourth Industrial Revolution discourse, the characteristics are the technology. Building on Schwab, several authors define the Fourth Industrial Revolution in terms of the technologies associated with the global trends (Effoduh, 2016; Philbeck & Davis, 2018a; Prisecaru, 2016). Naude for example, sees the Fourth Industrial Revolution as the integration of physical and digital production and consumption resulting from a,

> ...convergence of improvements in sensor, robotics with digital platforms, artificial intelligence and big data analytics, linked by Internet of Things..." resulting in "...mass customisation and hyper operationalisation of consumption through additive manufacturing (3-D printing) production as service, through new business models such as sharing and on demand economies (Naudé, 2018: 147).

Using this frame for his overtly techno-optimistic analysis, Naudé argues that Africa's failure to industrialise can be turned around as a result of the convergence of new technologies of the Fourth Industrial Revolution and a resurgence of start-up entrepreneurship.

In a special the Fourth Industrial Revolution edition of the prestigious *Journal of International Affairs*, in which Schwab writes the foreword, the World Economic Forum's senior staff Philbeck and Davis (2018a: 17) write, as if uncontested and incontestable,

> ...since 2016, the Fourth Industrial Revolution has been used to frame and analyse the impact of emerging technologies on nearly the entire gamut of human development in the early 21st century, from evolving norms and national political attitudes to economic development and international relations.'

Reinforcing the techno-centric conceptualisation of the Fourth Industrial Revolution, Philbeck & Davis (2018) argue that at a certain stage, a set of technologies emerge and combine in ways that have impacts far beyond incremental increases in efficiency.

> This is what causes the dramatic shifts in markets, informational flows, employment trends, environmental outcomes and shifts in the balance of global power (Philbeck & Davis, 2018b:18).

Philbeck and Davis (2018) do refine some of the technologically determinist bluntness of the initial conceptualisation of the Fourth Industrial Revolution in Schwab's (2016) book on the subject, which Schwab in his later work (2018), does too to some degree. They highlight that the Fourth Industrial Revolution builds on datafication associated with Third Industrial Revolution, all of which require massive amounts of Second Industrial Revolution energy to operate, which are not present across vast parts of the Global South.

> The layering of dependencies matters because it shows that the Fourth Industrial Revolution is best suited to examining technologies and systems that take the digital world for granted... The important thing is how to govern these technologies as part of broader systems not just individual capabilities to deal with complexity" (Philbeck & Davis, 2018: 21).

However, there is little discussion of how such governance might function, what institutional arrangements need to be put in place, or that such governance should be in the public interest, not just enable inclusion in the context of getting markets to be viable. In fact, governance is referred to only in the context of markets and business models: not public participation or democratic oversight, not citizens or consumers or civil society.

Alternative Framing in the Literature

This very techno-determinist perspective is very different from that offered by this author in her contribution to a publication released at the end of 2020 by the Mapungubwe Institute for Strategic Reflection (MISTRA). The dramatic changes in global power relations are attributed intensifying hyper globalisation that have changed the nature and interplays of States, markets and citizens, and that has resulted in novel forms of capital formation reflecting new powerful interests that coalesce to drive technological developments with uneven social and economic outcomes (Gillwald, A, 2020). With very little digital policy research emanating from South African universities to inform policy developments, MISTRA stepped into this academic breach producing the first academic collation of multidisciplinary perspectives on the Fourth Industrial Revolution, certainly from an African perspective. It provides the sobering cautionary about uncritically adopting dominant approaches to the Fourth Industrial Revolution.

> The challenge for Africa is not whether, but how and with what effect, these technologies will find systemic application. If the process is haphazard, the continent will find itself dictated to by experiences that are not attuned to its social contexts. (Mazibuko-Makena & Kraemer Mbula, 2020: viii)

However, ultimately the editors accede to the view that the Fourth Industrial Revolution provides,

> "...a useful framing...For all the critiques of the notion of a Fourth Industrial Revolution (the Fourth Industrial Revolution), the idea does capture the enormity of changes currently taking place in many areas of human endeavour, and uses this as its point of reference – rather than for example the frame" (Mazibuko-Makena & Kraemer Mbula, 2020: vii).

Pollitzer (2018)economies, and the environment will be like in the years ahead. The first is conceptualized as the Fourth Industrial Revolution (4IR also offers another framing of the Fourth Industrial Revolution by juxtaposing the Fourth Industrial Revolution frame with its primary focus on opportunities to improve the economies of industrialised countries of the Global North with the vision of the future offered by the United Nations Sustainable Development Goals (SDGs). In relation to improving the economies of the industrialised countries, she writes,

> The big transformational promise of the Fourth Industrial Revolution is in cyber-physical systems that will merge different digital technologies and integrate them within the physical, digital and biological spheres. This will produce deep and systemic societal changes at a larger scale and a more rapid rate than previously seen (Pollitzer, 2018: 3).

Because these systemic changes identified are still attributed to the technological changes and not the interests driving them, they are presented as inevitable and singular.

For the alternative vision Pollitzer (2018) offers UN Sustainable Development 2030 Agenda goals and targets which assumes that ICTs will make an impact, but declines to translate these expectations into concrete details, she contends. Pollitizer (2018) explores routes toward more equitable digital futures through scenario building, highlighting the risk that the realisation of the Fourth Industrial Revolution will extend the digital divide between the Global North and the Global South to an insurmountable level of digital inequality. Though Pollitzer's identification of the broader set of drivers of the Fourth Industrial Revolution goes beyond World Economic Forum's narrow conceptualisation, her framing of a digital divide narrowly relates to connectivity, which as discussed above does not adequately capture the multidimensional aspects of digital inequality. It is the absence of any politics, (as is the case of the UN SDGs framework itself) or economics that makes such a conceptual framework, despite its contribution, incapable of offering a transformative alternative to the World Economic Forum's framing of the Fourth Industrial Revolution.

Transformative vision

A more realistic transformative vision might be better found in the writing of Roberto Unger. In contrast to the conventional framing of a North - South dichotomy or mature economy and lagging developing economies in the World Economic Forum's discourse, Unger argues that the idea of a broad-based, inclusive knowledge economy has proved elusive, even to wealthy countries, because the degree to which it is able to meet its potential is determined by its scope. Even in mature nations it is only present across the economy at the fringes, "depriving the economy and labour force of powerful enhancing productivity, not only from machines but the transformation of our ability to innovate and cooperate" (Unger, 2019: 6).

While associated with the information technology sector, these productive processes transect every sector of the economy, which is what makes them revolutionary (and is what is common to general purpose technologies). But because it is currently only manifesting at the fringes of other sectors, its revolutionary potential is curtailed. The products and services of a small number of increasingly concentrated global firms, which have commoditised most of their activity, are used by firms and individuals across the globe, but these new productive methods are not shared by them, he contends. They "…may employ efficiency-enhancing gadgets as ways to forestall rather than begin the changes that would turn it into a protagonist of the knowledge economy" (Unger, 2019: 6).

The work of Unger, (2019) provides a far more profound analysis than that offered by Schwab, even in his later work Schwab (2018) in which he does recognise that policies adopted during these transformations will have a dramatic impact on who benefits, when and how. To deal with this Schwab proposes a new world order, Globalisation 4.0, on the grounds that the current governance and academic institutions are unable to deal with the complexity of the contemporary economy and society. But what is the proposed new world order?

> '... it refers to shaping a global collaborative architecture, which takes full advantage of the Fourth Industrial Revolution for the benefit of all. "It builds on open markets as a force for economic growth, but always strives for environmental sustainability and social inclusion' (Schwab, 2018: 15).

Without any analysis of concentrations of power, inequality, and environmental degradation it is unclear how the continued promotion of open markets will produce different outcomes.

Unger on the other hand contends that the failure of the "most advanced processes of production" to contribute to dealing with central economic challenges - stagnation and inequality – is that they have been quarantined to insular "vanguards of production" under the control of technological and entrepreneurial elites. Only a few global firms have enjoyed the benefits (profits) associated with it, with the bulk of global labour excluded from it. Were it more pervasive and inclusive, this "...most efficient practice of production with its attributes of fecundity and versality across all sectors..." he argues, has the potential to alter human life radically (Unger, 2019: 3–6).

The treatment of this production revolution, as only related to the new technologies associated with information communication and the internet, results from its insularity currently beyond those forms and sector. But more importantly this insularity is the cause of the economic stagnation and unimpressive impact of digital technologies on productivity, compared to previous production processes of the 'industrial revolution.'

Both Schwab and Unger believe there is no reason to assume that contemporary digital technologies are less revolutionary in their potential to previous revolutionary technologies. But while Schwab is concerned about required levels of leadership and absence of the requisite institutional framework to govern the diffusion of innovation driven by the private sector and to mitigate the associated disruption, for Unger the problem lies in the failure to extend productive processes to economy-wide innovation, beyond the fringes to which its diffusion is currently limited.

Containment of the knowledge economy to the fringes in all sectors of production has similarly powerful implications for inequality, Unger contends. The distinction between an insular, even if multisectoral vanguard and the rest of the economy – "a collection of rear-guards" – he says, "has become a powerful engine of inequality of opportunity and capability as well as of income and wealth". Because the effects of technologies are mediated by the institutional and cultural settings in which they take place, it will require more than a different way of regulating the market economy as suggested by Schwab (2018) and Philbeck and Davis (2018). For Unger, if the programme of the inclusive knowledge economy is to advance "...a break with the institutional and ideological settlement that has prevailed in these societies since the mid-20th century, even if only achieved incrementally... will require a change to our fundamental economic arrangements – its institutions and processes...". This requires a new style of education, the renewal of the culture of production and the reshaping of the economic institutions,

such as the intellectual property rights regime (Unger, 2019: 7–8). This framing of what is required to transform the current digital landscape provides a much more coherent basis for a transversal digital policy for the country.

Lack of institutionalisation of digital policy in South African knowledge system

In the Global North, policy formulation generally is the result of competing evidence from well-funded academic institutions and think tanks, with access to good, publicly available national macro, supply and demand-side indicators (virtually absent on the African continent) that can be interrogated in public policy processes. Yet in South Africa, despite constitutionally enabling administrative justice law, participation in public policy consultative processes in the telecommunications sector have been overwhelmingly dominated by the private sector, with only exceptional representation from academia.

Given the poorly developed digital policy research and training capacity base of the academy in South Africa perhaps this is not surprising. Even South Africa's 'first tier' research universities are not developing the data and digital indicators or undertaking the multidisciplinary research required to inform policy makers grappling with this dynamic, complex environment that underpins contemporary life[29].

Early efforts to get the necessary multidisciplinary approach to policy research for the development of institutional capacity of new democratic institutions (policy makers, parliamentary portfolio committee, regulators) off the ground within universities were stymied by not falling comfortably within the traditionally siloed disciplines of the university[30]. Seed funding from the state to create the first digital and telecommunication policy centre was exactly that and was not provided in a consistent and independent way that would ensure its sustainability. This situation was not helped when new programmes starting to engage critically with evolving digital policy.

In the one or two cases where digital policy programmes were able to launch within graduate schools with private sector or donor funding, they have not been formally supported by universities and remain

[29] See the https://researchictafrica.net/project/after-access-surveys/ for only public domain demand side data on ICT access and use that is used in national for technical assistance on digital policy across Africa and by UN agencies and the World Bank.

[30] Having served in the founding council of the first telecommunications regulator, the South African Telecommunications Regulatory Authority (SATRA) and before that the broadcasting regulator, the independent broadcasting Authority, the author together with government officials, activists and academics sought to establish a training programme for African policy makers and regulators. The LINK Centre was established initially at the Graduate School of Policy and Development Management (P&DM). A rare multidisciplinary policy and develop initiative at the time, P&DM allowed the Centre to be established with seed funding from the Department of Communications and the author having finished her term at SATRA was the first director. Once this had dried up the Centre was supported by Vodacom Foundation, but this also dried up when it became clear, as it had to the Communications Department, that the Centre was going be guided by the principle of academic autonomy. The Centre was various supported by other donor organisations, particularly the IDRC, and managed to develop a successful professional development certificate that has trained literally 100 of African public and private sector officials. It also managed without any financial support from the university to establish a master's programme that has had dozens of people pass through it under the directorship of Luci Abrahams and course convener Charley Lewis. The programme managed to insert itself into the university by asking very little from the university, securing its own funding navigating its own way through the South African Qualifications Authority, with minimal university support.

largely under-resourced. The programmes are unable to access the subsidies awarded to the university and appoint permanent faculty from the fees generated from their programme. As a result, research outputs are close to non-existent. There are no incentives or fees waivers for students to register for doctoral programmes, with little to no resources other than the scarce non-remunerative appointment of supervisors from outside of the academy to support the development of doctoral programmes, making student throughput low[31].

There have been substantial public investments made through the National Research Foundation (NRF) into innovation research with the creation, with foreign funding, of several research chairs in South Africa and on the continent, but none of these have an explicit policy focus. In the past decade there have been cutbacks in research funding[32]and public subsidies to universities. Public investment has been directed to the state research councils (the Centre for Scientific and Industrial Research (CSIR) and the Human Sciences Research Council (HSRC). Increasingly the government has appointed the CSIR to undertake research for policy processes, including digital policy research, but the results have not been encouraging [33]. Despite there being no public funding of independent digital policy research at public universities or thinktanks, the Ministry of Science and Technology has also been the champion of a World Economic Forum E-affiliated Centre for the Fourth Industrial Revolution that has been established at the CSIR to support policy development at an affiliate fee of apparently $1million (Mandaha, 2019).

Within most South African universities, research continue within traditional silos, despite commitments to multidisciplinary and transdisciplinary research. Initiatives to develop cross-cutting policy, governance or developmental multidisciplinary research required for digital policy and even formalised training and post-graduate programmes have been ghettoed in self-funded initiatives, with research and teaching efforts not recognised within traditional performance indicators for disciplines and therefore for career advancement[34].

There are pockets of research on ICT and policy and regulation, economic and competition regulation, and ICT for Development (ICT4D), cybersecurity in computer science departments, and intellectual property rights and data protection expertise in law departments, but there is little of the multi- and trans- disciplinary research being undertaken at postgraduate level required to deal with arguably one

---

[31] This reflects the experience of the author as she sought with colleagues to develop professional development and later master's programmes in ICT policy and regulation at the Graduate School of Policy and Development at the University of Witwatersrand between 1999 and 2008, and an African-wide research network on ICT policy and regulation to provide teaching programmes with a local evidence base. She had a similar experience at the University of Cape Town, first the Graduate School of Business and subsequently at the Nelson Mandela School of Public Governance, where she sought unsuccessfully to develop a full-fledged doctoral programme for African Scholars.

[32] See https://www.groundup.org.za/article/nrf-cuts-hurt-south-africas-scientists/ and https://www.news.uct.ac.za/article/-2017-11-29-universities-sa-expresses-concern-relating-to-the-cuts-in-funding-for-research-development

[33] This was raised for example with the assessment of the viability of the Wireless Open Access Network proposed for High Demand Spectrum that CSIR were enlisted to undertake. While an excellent study of the amount spectrum required for the WOAN to operate technically efficiently, the motivation presented to cabinet by the Department had no economic analysis associated with it. At the time, and for a long time afterwards the CSIR report was not available to the public.

[34] These observations arise from formal evaluations of digital centres at UCT and Wits University with which the author was involved.

of the most challenging planetary policy problems facing us.

The Fourth Industrial Revolution initiatives, with policy components in them, have sprung up at universities over the last few years. These are largely private sector funded, often by local or global corporations with vested interests in this area. With many located in business schools, it is perhaps unsurprising that they adopt an uncritical, World Economic Forum-type approach to the subject. As Sutherland (2020) points out, in practice this techno-industrial approach comes not from the economic historical analyses of industrial revolution, but from a recent tradition of auto-cannibalism of business models. A central concept of this is the dynamic capability or the means by which an organisation adapts its resources to respond to disruptions as "firms re-imagining their businesses before rivals do it for them" (Sutherland, 2020: 239)generating criticism for its neoliberal rhetoric echoing the World Economic Forum (WEF).

The Fourth Industrial Revolution policy and implementation in South Africa

As the following empirical assessment drawing on the National Development Plan Digital Futures (Gillwald, 2020b) report demonstrates, there is little reference to any other literature or weighing of other policy frames for the intensifying process of digitalisation and datafication that are presenting some. The World Economic Forum-inspired policies have been rolled out in the Department of Science and Innovation (DST), Arts and Culture, the Department of Trade, Industry and Competition (DTIC), and the Department of Communication and Digital Technologies (DCDT). With the DSI at the cutting edge of research and development (R&D) and innovation policy, it has had the greatest capacity to respond to the Fourth Industrial Revolution call based on a long and strong technology and innovation policy agenda, bringing out an updated White Paper in early 2019 to respond to the challenges of the Fourth Industrial Revolution.

The DTIC refers to the Fourth Industrial Revolution in the Industrial Policy Action Plan (IPAP) 2018/19–2020/21, and the establishment of a Chief Directorate: Future Industrial Production and Technologies (FIP&T) unit to investigate the possible effects of the Fourth Industrial Revolution and prepare governmental capacity for addressing the subsequent challenges. The plan perhaps more than anything else, highlights several risks associated with zero-sum outcomes for the country. The Ministry of Higher Education at the time of the review in 2019 had accepted the mandate of re-gearing the system to produce the high-level skills required to prepare South Africa for the digital future, but perhaps with less preoccupation with the Fourth Industrial Revolution as a revolutionary moment than other departments.

The Fourth Industrial Revolution discussion paper that arguably most reflects the World Economic Forum's thinking emerged from the then Department of Telecommunications and Postal Services, which recently merged again with the Department of Communications (DoC) to become the DCDT. This is not surprising, since the Department was the entry point for the World Economic Forum, striking a partnership with South Africa as the third African country for their 'Internet for All' initiative after Rwanda and Uganda - two countries with amongst the lowest Internet penetration in Africa (Gillwald & Mothobi, 2019)and particularly broadband technologies, have been identified as critical drivers of social and economic growth and development. Smartphones, in particular, have revolutionised the telecommunications industry by becoming the principal means of Internet connectivity. After years of sluggish uptake of the Internet with the high cost of fixed broadband services, requiring\nexpensive

computer connectivity and relatively high digital literacy, the initial rapid mobile Internet adoption appears to have flattened out in many countries.\n\nIn addition, a number of these countries are below the 20% critical mass believed to be necessary to enjoy the network effects associated with improved efficiencies and enhanced information flows for economic growth and innovation. Research ICT Africa's (RIA's. It also served as the Secretariat for the Fourth Industrial Revolution Commission. As a result of this relationship Accenture was commissioned to prepare the Department's discussion paper on Preparing South Africa for the Fourth Industrial Revolution[35]. Together with McKinsey, Accenture are international consultancies that partner with the World Economic Forum globally on the Fourth Industrial Revolution. Without any references or specified data sources or methodology – other than that the model is the outcome of a WEF-Accenture collaboration – the report claims that the Fourth Industrial Revolution technologies across industries in South Africa can, over the next decade, contribute R5 trillion worth of social and economic value. It also claims that they will create four million jobs[36].

Presidential Commission on the Fourth Industrial Revolution

The apex body on the Fourth Industrial Revolution, and the proposed vehicle for catalysing the Fourth Industrial Revolution in South Africa, is the Presidential Commission on the Fourth Industrial Revolution, which President Ramaphosa heads together with a leading scholar on artificial intelligence and vice-chancellor of the University of Johannesburg. The erroneous conflation of the Fourth Industrial Revolution with digital transformation in his announcement of the Fourth Industrial Revolution Commission in 2018 is reflected in the mandate of the Commission and the arising report presented to the President in late 2020 after a year-long study. Despite indicating the adoption of a 'human-centric approach' and providing the context of South Africa's structurally constrained economy and poor state of human development, the technological deterministic lens of the report prevents it from delivering on the expressed intention of the report to align with the National Development Plan's commitment to create the conditions necessary for "…a virtuous cycle of employment, growth, poverty reduction and rising living standards". This failure is reflected in its key recommendations which offer no policy direction for broader digital transformation, though they are pertinent to the data driven technologies that propel the Fourth Industrial Revolution:

- building human capacity in the area of the Fourth Industrial Revolution;
- establishing the National Artificial Intelligence Institute;
- building human capacity in the area of the Fourth Industrial Revolution;
- establishing the National Artificial Intelligence Institute;
- creating the Advanced Manufacturing Institute (AMI);
- the establishment of a National Data Centre; and

---

[35] Although the Accenture copyrighted report Enabling South Africa 4.0 *Becoming 4IR Ready – A Government-Led Approach* was made available for comment by the then Department of Communications and Postal Services, to a select group of stakeholders it appears not to be publicly available.

[36] For a quick reality check, Centre for Economic Development and Transformation indicates the average growth rate has hovered between 2 % and negative growth over the past two years and best long-term growth predictions under current policy conditions estimate 3.5%. We have produced 270 000 to 300 000 jobs on average over the past five years and we have about 700 000 new young people entering the job market a year. They indicate that a growth rate of around 10% will be required to absorb these new entrants into the economy.

incentivising SMMEs for the adoption of the Fourth Industrial Revolution technologies and the emergence of future industries and platforms. (PC on the Fourth Industrial Revolution, 2020)

Although the Fourth Industrial Revolution Commission Report identifies five key pillars for the successful take-off of the Fourth Industrial Revolution (technology invention and innovation; people and skills; infrastructure, resources and natural environment; economic growth and inclusivity; and stakeholder relations and governance), importantly missing from the report's alignment with the NDP is the overriding commitment to equality.

These pillars identify important areas of development that should certainly form a critical part of a much-needed transversal digital policy[37]to harness the efficiency and productivity gains associated with increasingly globalised processes of digitalisation and datafication. But the report of the Fourth Industrial Revolution Commission does not address how they are to be achieved other than in the broadest sweeps. Like the Accenture report for the Department of Communication, if does indicate why there has been little progress, or what needs to be done differently in meeting these pre-conditions for South Africa to be able to harness the benefits of the Fourth Industrial Revolution (Gillwald et al., 2018).

Arguably more, importantly considering the global nature of these digital public goods, there are no insights into the challenges of global governance, particularly on the regulation of the small global elite that currently drive digital developments, or how to safeguard citizens' rights, prevent known harms and mitigate associated risks without any jurisdictional control over them (See Gillwald & van der Spuy, 2019).

Despite it seeking to align with the National Development Plan and the central policy challenges of the country to address the triple scourge of poverty, inequality and unemployment, as the very circumscribed recommendations of the report demonstrate, the technologically deterministic, ahistorical framing of the Fourth Industrial Revolution that it draws on prevents this.

Conclusions and recommendations

This paper has sought to show how the very successful World Economic Forum lobby in the country was largely uncontested in the absence of any public investment in local research and capacity building in the area of digital policy, regulation and governance that might have mainstreamed more social and economically just discourse and developed the necessary empirical evidence to provide digital vision for the country aligned with constitution and the National Development Plan. This would not only be inward focusing, but prepare the country for the policy challenges arising from the new hyper-globalised environment (Marsden, 2001)with widely predicted increases in interactivity, choice, personalization, and the ability to micro pay for a la carte programming . Whereas broadcasting was licensed, controlled and regulated tightly by national governments (or even owned as a monopoly service, undergirded by unevenly distributed global digital networks.

In pursuit of the much needed policy experimentalism in developing countries required to rectify the failures of past policy to reduce digital inequality, this paper has sought to demonstrate how an alternative approach to the globally intensifying processes of digitalisation and datafication could have

[37] (See Digital Britain; Digital 2020: Canada; the Australian Digital Strategy 2018 – 2025 or the entirely comprehensive digital society case of e-Estonia)

the transformative effects anticipated in the constitution of the Republic of south Africa, and make progress towards the national ICT targets in national policy and the National Development Plan, and those underpinning most of the 17 SDGs, now also co-opted into the Word Economic Forum's Great Reset agenda referred to above.

While the Fourth Industrial Revolution is a convenient way of packaging history and for mobilising people, the current diversion of policy focus and resources from existing supply and demand side challenges will affect the country's ability to respond effectively and equitably to the complex-adaptive global digital ecosystem. Rather than focusing narrowly on the potential and dangers of so-called Fourth Industrial Revolution technologies, South Africa needs to develop a transversal digital policy that is far more comprehensive than one focusing on artificial intelligence, machine learning, blockchain and drones, although these would be important forward-looking parts.

As proposed in the *Digital Futures* report prepared for the National Planning Commission, to properly inform the development of a digital economy, South Africa will need to propose a comprehensive, integrated national project that address the entire ICT. Such an integrated policy will enable the country to create the necessary conditions to harness the benefits of advanced technological developments and mitigate the risks associated with them. A transversal policy will need to cut across all government departments to enable high-level integrated planning and implementation, as well as across the public and private sector for the coordination required for an equitable and competitive digital economy.

With public investments in the development of strong digital indicators and policy research the country would have been better placed not only to rise to the challenges of post-Covid economic reconstruction but to optimise opportunities such as those offered by the African Continental Free Trade Movement. It would have allowed it to engage more effectively within regional and global governance processes, importantly in relation to trade, global tax regime reform (which has the potential to expand both economic activity and the tax base required for much needed social investment and protection), and cybersecurity and data governance.

Although it would be ideal to develop several strong competing centres of digital policy research excellence to inform this dynamic and complex field, the development of such an evidence and knowledge base for the country will require a fast-tracked national response that may in the first instance leverage pockets of excellence across the country into a co-ordinated national project. This could be done through:

- allocating any funding available to a national project aimed at developing a dynamic transversal digital policy;
- establishing a virtual national digital policy institute drawing together specialised research expertise from different areas at different universities;
- develop inga national evidence based on multidisciplinary research and supply and demand side digital indictors (open source); and
- developing capacity, including professional multidisciplinary digital (non-sectoral) policy development, post graduate education and doctoral research.

References

Effoduh, J. O. (2016). *The Fourth Industrial Revolution By Klaus Schwab*. 10. Https://Digitalcommons.Osgoode.Yorku.Ca/Thr/Vol3/Iss1/4

Fink, C., & Kenny, C. J. (2003). W(H)Ither The Digital Divide? *Info*, *5*(6), 15–24. Https://Doi.Org/10.1108/14636690310507180

Gillwald, A. (2020). A New Digital Deal Rather Than A Fourth Industrial Revolution Policy? In *Leap4.0: African Perspectives on the Fourth Industrial Revolution.* MISTRA.

Gillwald A. (2020). Openness In Telecommunications Reform and Practice: The Case of Open Access Broadband Networks, Public Wi-Fi and Zero Rating. In *Open Development.* MIT Press IDRC. Https://Www.Idrc.Ca/Sites/Default/Files/Openebooks/Opendevelopment/9781552505953.Html#Ch8

Gillwald, A. (2020a, July 28). *Digital Inequality Reflects Structural Inequality*. Https://Www.Youtube.Com/Watch?Time_Continue=31&V=I8bx7tkjjgu&Feature=Emb_Logo

Gillwald, A. (2020b). *Digital Futures: South Africa's Readiness for The Fourth Industrial Revolution*. National Planning Commission. Https://Researchictafrica.Net/Wp/Wp-Content/Uploads/2021/01/021220_Digital-Futures_Sas-Digital-Readiness-For-the Fourth Industrial Revolution_01. Pdf

Gillwald, A., & Mothobi, O. (2019). *After Access 2018: A Demand-Side View of Mobile Internet From 10 African Countries* (After Access 2018: A Demand-Side View of Mobile Internet From 10 African Countries After Access: Paper No. 7 (2018); Policy Paper Series No. 5). Research ICT Africa. Https://Researchictafrica.Net/Wp/Wp-Content/Uploads/2019/05/2019_After-Access_Africa-Comparative-Report.Pdf

Gillwald, A., Mothobi, O., & Rademan, B. (2018). *The State of ICT In South Africa* (After Access Policy Paper No. 5, Series 5; Policy Paper Series 5: After Access-Assessing Digital Inequality in Africa). Research ICT Africa. Https://Researchictafrica.Net/Wp/Wp-Content/Uploads/2018/10/After-Access-South-Africa-State-Of-Ict-2017-South-Africa-Report_04.Pdf

Gillwald, A., & Van Der Spuy, A. (2019, November). *The Governance of Global Digital Public Goods: Not Just a Crisis for Africa*. Giganet Annual Symposium, Berlin, Germany. Https://Www.Giga-Net.Org/2019symposiumpapers/34_Gillwald_Vanderspuy_Global-Governance.Pdf

Government Of South Africa. (2012). *The National Development Plan: Vision 2030*. Government Gazette.

Gunkel, D. (2003). Second Thoughts: Toward A Critique of The Digital Divide. *New Media & Society - NEW MEDIA SOC*, *5*, 499–522. Https://Doi.Org/10.1177/146144480354003

Guterres, A. (2020). *Tackling The Inequality Pandemic: A New Social Contract for A New Era*. Https://Www.Nelsonmandela.Org/News/Entry/Annual-Lecture-2020-Secretary-General-Guterress-Full-Speech

Ivan Wecke. (2021, August 16). *Conspiracy Theories Aside, There Is Something Fishy About the Great Reset*. Opendemocracy. Https://Www.Opendemocracy.Net/En/Oureconomy/Conspiracy-Theories-Aside-There-Something-Fishy-About-Great-Reset/

Khan, M., & Roy, P. (2019). *Digital Identities: A Political Settlements Analysis of Asymmetric Power and Information*. Https://Eprints.Soas.Ac.Uk/32531/1/ACE-Workingpaper015-Digitalidentities-191004.Pdf

Leys, C. (1977). Underdevelopment And Dependency: Critical Notes. *Journal Of Contemporary Asia*, *7*(1): 92–107. Https://Doi.Org/10.1080/00472337785390081

Mandaha, D. (2019). *CSIR Welcomes New Minister and Deputy Minister | CSIR*. Https://Www.Csir.Co.Za/Csir-Welcomes-New-Minister-And-Deputy-Minister

Marsden, C. (2001). *The Challenges of Standardisation: Towards the Next Generation Internet*. Https://Doi.Org/10.2139/Ssrn.287634

Mazibuko-Makena, Z., & Kraemer Mbula, E. (2020). *Leap 4.0 African Perspectives on The Fourth Industrial Revolution*. Jacana Media.

Rectenwald, M. (2021, November 7). *What Is the Great Reset?* Https://Www.Michaelrectenwald.Com/Essays/What-Is-The-Great-Reset

Miller, D. A., & McCandless, E. (N.D.). *What South Africa Needs to Forge a Resilient Social Compact for Covid-19*. The Conversation. Retrieved 6 December 2021, From Http://Theconversation.Com/What-South-Africa-Needs-To-Forge-A-Resilient-Social-Compact-For-Covid-19-138171

Moll, I. (2021). The Myth of The Fourth Industrial Revolution. *Theoria*, *68*(167), 1–38. Https://Doi.Org/10.3167/Th.2021.6816701

Naudé, W. (2018). Brilliant Technologies and Brave Entrepreneurs: A New Narrative for African Manufacturing. *Journal Of International Affairs*, *72*(1), 143–158. Http://Www.Jstor.Org/Stable/26588350

Presidential Commission on the Fourth Industrial Revolution. (2020). *Diagnostic Report of Th Presidential Commission on The Fourth Industrial Revolution*. Presidency, RSA.

Philbeck, T., & Davis, N. (2018a). The Fourth Industrial Revolution: Shaping A New Era. *Journal Of International Affairs*, *72*(1): 17–22. Http://Www.Jstor.Org/Stable/26588339

Philbeck, T., & Davis, N. (2018b). The Fourth Industrial Revolution: Shaping A New Era. *Journal Of International Affairs*, *72*(1): 17–22.

Piketty, T. (2014). *Capital In The 21st Century*. Harvard University Press.

Pollitzer, E. (2018). Creating A Better Future: Four Scenarios for How Digital Technologies Could Change the World. *Journal Of International Affairs*, *72*(1): 75–90. Http://Www.Jstor.Org/Stable/26588344

Prisecaru, P. (2016). Challenges Of the Fourth Industrial Revolution. *Knowledge Horizons - Economics*, *8*(1): 57–62. Https://Tinyurl.Com/38paxrscsassen, S. (2013). Expelled: Humans in Capitalism's Deepening Crisis. *American Sociological Association, Volume 19*(Number 2), 198–201.

Schwab, K. (2018a). Foreword. *Journal Of International Affairs*, *72*(1), 13–16. Http://Www.Jstor.Org/Stable/26588338

Schwab, K. (2018b). Foreword. *Journal Of International Affairs*, *72*(1), 13–16. Http://Www.Jstor.Org/Stable/26588338

Sutherland, E. (2020). The Fourth Industrial Revolution – The Case of South Africa. *Politikon*, *47*(2), 233–252. Https://Doi.Org/10.1080/02589346.2019.1696003

Transnational Institute. (2016, January 15). *Who Does the World Economic Forum Really Represent?* Transnational Institute. Https://Www.Tni.Org/En/Publication/Who-Does-The-World-Economic-Forum-Really-Represent

Trauth-Goik, A. (2021). Repudiating The Fourth Industrial Revolution Discourse: A New Episteme of Technological Progress. *World Futures*, *77*(1), 55–78. Https://Doi.Org/10.1080/02604027.2020.1788357

Unger, R. M. (2019). *The Knowledge Economy*. OECD. Https://Www.Oecd.Org/Naec/THE-KNOWLEDGE-ECONOMY.pdf

Education 4.0: Towards the Transformation of the South African Higher Education

J. N. Zongozzi

Institute for Open Distance Learning

University of South Africa

zongojn@unisa.ac.za

Abstract

In South Africa, increasingly students demand equitable quality higher education for all. The historical context of South Africa makes transformation in higher education a national imperative. Meanwhile, elsewhere in the world students are part of fascinating, fun, smart, inspiring, and empowering learning experience known as 'Education 4.0', which is fuelled by the Fourth Industrial Revolution. In responses to the discourse, started by the Council on Higher Education (CHE), on whether the Fourth Industrial Revolution could be advance within the context of transformation of higher education in South Africa, this paper reports about a concept analysis study, which was aimed at locating 'Education 4.0' concept within the agenda for the transformation of higher education. As a result of this analytical process, a conceptual framework for understanding 'Education 4.0' within the context of transformation of the South African higher education emerged. The framework consists of antecedents, attributes, and a model case, among others. It suggests that if 'Education 4.0' is configured adequately, it could result in positive consequences towards realising the transformation goals.

Keywords: Fourth Industrial Revolution, Education 4.0, transformation, South Africa, higher education

Introduction and background

The current state of higher education in South Africa can largely be attributed to the legacy of the education policies instituted under apartheid. As a result, South Africa's education system differed significantly from that of other countries. Such distinguishing features include the extent to which racially entrenched attitudes and the institutionalisation of discriminatory practices contribute to significant inequalities in the delivery of education, a reflection of society's fragmentation and disparity (Engelbrecht, 2006). During the apartheid era, higher education was a fiercely contested space. This gave birth to an obdurate legacy of social as well as economic inequalities underpinned by a complex skein of discriminatory political and cultural attitudes, disposition, and orientations. Despite the unyielding obduracy and resistance towards the ideal of transformation (Development Bank of South Africa, 2010), the government of post- 1994 continued devising measures to transform the higher education sector.

Arguably, with the death of apartheid, discriminatory policies have been abolished, and transformation has become a topical issue in the country, with greater emphasis on justice and recourse. In this perspective, access to affordable quality higher education has been critically situated to promote acceptable conceptions of justice and redress (Akoojee & Nkomo, 2007). However, transformation in the sector includes a variety of other factors, such as increasing access, improving student performance, increasing demographic composition for students and staff from previously disadvantaged population

groups, improving resource efficiency, reforming curriculum, changing institutional cultures and fostering epistemological access (Council on Higher Education, 2020). A series of transformation-oriented legislation has been adopted to address the above-mentioned imperatives.

Subsection 29(1) of the Constitution of the Republic of South Africa (South Africa, 1996) emphasises everyone's right to further education, which the State, "through reasonable measures, must make progressively available and accessible". This right to improved access to quality education and jobs, especially for historically marginalised communities, was reaffirmed in the National Development Plan (NDP) of South Africa Vision 2030, which calls for the prioritisation of efforts to ensure appropriate and affordable programmes for the development of skills, coupled with equitable opportunity for productive and gainful employment of such groups (NDP, 2011). For example, through the newly adopted *Strategic Policy Framework on Disability for the Post-School Education and Training Sector* (DHET, 2018), the government aims to accelerate change and redress with a view to complete inclusion, integration and equity for Students with Disabilities (SwDs) in higher education. Other transformation-driven policies and legislation include the following: *White Paper on the Rights of Persons with Disabilities (2015); White Paper on Education and Training (1995); National Plan for Higher Education (2001); Education White Paper 3 on the Transformation of the Higher Education System (1997); Education White Paper 4: A Programme for the Transformation of Further Education and Training (1998); Education White Paper 6 on Special Needs Education: Building an Inclusive Education and Training System (2001); Higher Education Act 101 of 1997; Skills Development Act 97 of 1998; White Paper for Post-School Education and Training - building an expanded, effective and integrated post-school system (2013);* and the *Policy Framework for the Realisation of Social Inclusion in the Post-School Education and Training System (2016).*

Globally, efforts to utilise technology in support of remote learning and open distance and e-Learning (ODeL) are emerging and evolving quickly partly due to the Covid-19 pandemic. The fusion of Fourth Industrial Revolution technologies in ODeL such as smart devices, robotics and other assistive devices makes the facilitation of remote learning easier. ODeL "focuses on removing barriers to access learning, flexibility of learning provision, student-centredness, supporting students and constructing learning programmes with the expectation that students can succeed" (University of South Africa, 2018, p.2). For that reason, ODeL is cited in *the Education White Paper 3: A Programme for the Transformation of Higher Education (1997)* as having a significant role to play in transformation in terms of widening access, diversity, and improving efficiency. This is due to the multiple contexts in which learning happens in this mode, such as a variety of platforms, at the student's pace, through various media, and through various teaching and learning methods. As a result, the government's vision of fostering and advancing social justice can be fulfilled by this mode of teaching and learning, as ODeL institutions can host a greater number of students at a time (Zongozzi, 2020a). This also explains why, as technology improves, more people are relying on ODeL courses (Lee and Choi, 2011).

While the envisaged outcomes of transformation, such as increased accessibility, improved academic performance, and curriculum transformation are thought to be possible by distance education and resource-based learning, progress has been steady (Pandor, 2018). This was confirmed by Gumede and Biyase (2016) who observed that while there has been some success in legislative interventions, policy development, curriculum reform, and the deployment of innovative ways of delivering education, there are still many difficulties ahead. The quality of education is one of the most pressing problems in the twenty-seven years since the birth of democracy. However, the use of the Fourth Industrial Revolution technologies to deliver higher education remotely through online platforms is relatively

new in South African and became a force to reckon with only with the emergence of the Covid-19 pandemic (Mhlanga & Moloi, 2020).

Problem statement

Despite the pressures brought about by the Covid-19 pandemic, the higher education sector seems to be hesitant to embrace technology as a teaching and learning aid (Ghavifekr & Rosdy, 2015). Nonetheless, the transition to Fourth Industrial Revolution-driven teaching and learning, also known as 'Education 4.0', seems to be unavoidable, simply because the Fourth Industrial Revolution has the potential to contribute significantly to the achievement of transformation imperatives in South Africa (Council on Higher Education, 2020) as well as to the Sustainable Development Goals (SDGs).

'Education 4.0' is a concept used to describe some Fourth Industrial Revolution developments in the field of education (Butt, Siddiqui, Soomro & Asad, 2020). Although there have been some studies on the Fourth Industrial Revolution in South African higher education focusing specifically on curricula of Industrial Design programmes (Adelabu & Campbell, 2020), infrastructure development (Nkosi, Aboginije, Mashwama & Thwala, 2020), perceptions of the education sector on the Fourth Industrial Revolution (Oke & Fernandes, 2020), and preparing the future workforce for the Fourth Industrial Revolution (Wessels, 2020), none of the studies fully placed the concept 'Education 4.0' within the context of transformation of higher education.A possible reason for this is that there is no consensus on what "Education 4.0" entails and on the definition that qualifies to illustrate its attributes (Oke & Fernandes, 2020).

The purpose of the analysis presented in this paper is to define, among other things, the features, antecedents, and implications of 'Education 4.0' in the context of higher education transformation in South Africa. The analysis is undertaken through the use of a conceptual framework for understanding the relationship between Education 4.0 and the processes needed to advance the Fourth Industrial Revolution in higher education within the context of transformation in the sector.

Methodological considerations

The researcher employed an inductive-discovery approach that focused on identifying relevant aspects of the concept in an attempt to uncover what is common in its application. A concept analysis was conducted to obtain the operational definition, and to define attributes, antecedents and consequences of the concept within the South African higher education reform framework. The study went on to construct a model case for the concept in question in order to gain logical consistency (Sun & Knobf, 2008). The ability to examine and describe a concept and its application is what makes concept analysis useful (Maputle & Donavon, 2013). The aim is to grasp the meaning of the concept (Maputle & Donavon, 2013) so as to be able to understand the concept clearly and distinctly, and to unambiguously describe and distinguish it from other concepts, including in the ways it is applied to different contexts in the real world (Chabeli & Muller, 2004).

The concept analysis method is a process involving the following eight steps (Walker and Avant, 2014, p.166): select a concept; determine the aims or purposes of analysis; identify all uses of the concept that you can discover; determine the defining attributes; identify a model case; identify borderline, related, contrary, invented and illegitimate cases; identify antecedents and consequences; and define empirical referents.

Scholarly work and policy content pertaining to issues of transformation and the Fourth Industrial Revolution in higher education, both locally and internationally, were strategically considered for the purpose of this research. This study recognises that using the phrase 'transformation of higher education' as the primary search key for locating the use of 'Education 4.0' in the context of transforming higher education in South Africa may, be a constraint. Alongside the Fourth Industrial Revolution and 'Education 4.0', other terms, expressions and related concepts (such as decolonising the curriculum, inclusive education, accessible learning material) were used (Wessels, 2020).

To accomplish the aims of the study, which included identifying the shared meaning and attributes of 'Education 4.0' and its application in the context of higher education transformation, an exhaustive literature search was undertaken. Relevant literature that discussed the Fourth Industrial Revolution and teaching and learning in higher education were obtained by searching in relevant books and articles within the Unisa Library Catalogue, Google Scholar, Eric, Education Source, Africa Wide, Academic search premier (EBSCO), Emerald, IEEE, ProQuest, Scopus – Elsevier, Sage Publications, The Directory of Open Access Journals, Springer, Social Science Research Network, Science Direct, Sabinet, Unisa Library Repository and Taylor & Francis databases, among others. Boolean Operators were used to search for books and articles using the following key terms and phrases: "fourth industrial revolution" OR "4th industrial revolution" OR "the Fourth Industrial Revolution" OR "industrial revolution 4.0" OR "Education 4.0" AND "transformation of teaching and learning" OR "decolonising the curriculum" OR "inclusive education" OR "accessible learning material". Apart from scholarly sources, applicable government documents were used. These were obtained from the website of the Department of Higher Education and Training (DHET) of South Africa.

A qualitative content analysis was used to classify text units (sentences or paragraphs) in which the concept 'Education 4.0' appears in order to determine the concept's attributes, antecedents, and consequences. These passages from primary texts were read using a pragmatic, thematic hermeneutic approach to find the concept's meaning within the different contextual dimensions of the texts (Wessels, 2020).

A conceptual framework for understanding 'Education 4.0' within the context of transformation of the South African higher education

This section reports on the concept analysis steps followed in the development of a conceptual framework for understanding the concept "Education 4.0" within the context of transformation of the South African higher education.

Selection of the concept

The identification of an appropriate concept to be examined is the first step in the concept analysis process (Walker & Avant, 2014). Over time, industrial revolutions have essentially changed human lives, moving from hand labour and mechanised labour to computerisation (Yusuf, Walters & Sailin, 2020). The concept 'Education 4.0' has been a buzzword among educators (Hussin, 2018) since the executive chairman of the World Economic Forum declared the Fourth Industrial Revolution (Schwab, 2017). It has significantly influenced how universities in South Africa and around the world see or approach institutional processes, especially teaching and learning (Waghid, Waghid & Waghid, 2019). Some scholars regard 'Education 4.0' as a response to the needs of the Fourth Industrial Revolution where human and technology are aligned to enable new possibilities (Hussin, 2018). Such alignment

is evident in the definition of 'Education 4.0' by Himmetoglu, Aydug and Bayrak (2020) as a form of teaching and learning comprising of the following defining components: open access, individualised education, mental transformation, integration of digital technologies to education, seamless learning environments, lifelong learning, exploratory education and multidisciplinary education. There is, however, no consensus about what it means or a definition that qualifies to explain its characteristics, especially in the context of transforming teaching and learning in South Africa (Oke & Fernandes, 2020). The concept 'Education 4.0' was considered appropriate for analysis in view of Ocholla and Ocholla's (2020) claim that a response to the Fourth Industrial Revolution cannot occur without adequate conceptualisation and contextualisation.

Aims of the analysis

The aim of this concept study is to gain as much insight as possible into the features and significance of the phenomena that 'Education 4.0' applies to in the light of South African higher education transformation (Walker & Avant, 2014; Wessels, 2020). As a result, the study seeks to provide a means of determining the concept's shared meaning when used in the above context. The study also defined the distinguishing characteristics of 'Education 4.0', as well as the distinctions between it and similar but unrelated concepts.

Uses of the concept 'Education 4.0'

It is necessary to understand the different ways in which a concept (Walker & Avant, 2014) is used, while trying to find out what it entails. Though the concept in question is used in a similar way in the academic literature, the presence of several forms in which it is employed separates it. Its mother concept is the Fourth Industrial Revolution, which is generally defined as "a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres" (Waghid *et al*., 2019, p.2; Ocholla & Ocholla, 2020, p.357), is applicable to various contexts and sectors including industry, e-commerce, health, social media and education (Ally & Wark, 2020). Hence the use of Industry 4.0 to refer to the Fourth Industrial Revolution innovations relating to the industry (Yusuf *et al*., 2020) and 'Education 4.0' for those relating to education (Butt *et al*., 2020).

Kayembe and Nel (2019) view the Fourth Industrial Revolution as the present and evolving environment in which new technologies and trends such as the Internet of Things (IoT) and artificial intelligence (AI) are altering the way we live and work. According to Grinshkun and Sipovskaya (2020), the Fourth Industrial Revolution is a compounding effects of multiple 'exponential technologies' such as AI, biotechnologies and nanomaterials. Furthermore, the Fourth Industrial Revolution, in the work of Mhlanga and Moloi (2020, p.2), is described as "the advent of cyber-physical systems involving entirely new capabilities for people and machines". In agreement with the above authors, Whalley *et al*., 2020, p.79) relate the concept of the Fourth Industrial Revolution to a ubiquitously connected, pervasively proximate world in which diverse contexts are brought into proximity and are able to interact in ways that were implausible years ago.

Therefore, the Fourth Industrial Revolution is widely regarded as having an effect on nearly every sector around the world by transforming systems of production, management, and governance processes (Scepanovi, 2019). Within the higher education context, expanding access, optimising learning performance, growing demographic representation for students and teachers, enhancing resource efficiency, implementing curriculum reform, transforming institutional environments, and

fostering epistemic access are among the many aspects of the sector's transformation (Council on Higher Education, 2020). Multiple contexts that may be conducive for such transition initiatives were described in the *Education White Paper 3: A Programme for the Transformation of Higher Education*, including studying through different places, at the student's pace, and using different media and teaching and learning approaches. Thus, in the light of transforming education in South African, 'Education 4.0' applies to the use of technology-assisted learning to meet such imperatives such as more open learning materials and improved student achievement by implementing the following:

- Use of technology-based tools and services to promote non-traditional teaching and learning, while inspiring students to think out of the box. By so doing, 'Education 4.0' addresses the needs of a modern and rapidly developing world that is transitioning from an agricultural to an industrial society (Butt *et al*., 2020).
- Ruptured pedagogical methods in which teachers and students participate in pedagogic spaces autonomously and deliberatively as equals (Waghid *et al*., 2019).
- Exposing students to more project-based learning and shifting the main learning tasks from the teacher to the students (Hussin, 2018).
- Promotion of continuous professional development and lifelong learning (Ocholla & Ocholla, 2020).
- Enabling the development of students in emerging disciplines like robotics, artificial intelligence, genomics, data science and nanomaterials (Yusuf *et al*., 2020).
- Provision of personalised learning and flexible learning opportunities for all citizens, regardless of their status and location (Ally & Wark, 2020).
- Allowing student mobility and internationalisation of higher education through the establishment of institutional linkages, both locally and globally, such as twinning programmes and professional qualifications, and Massive Open Access Courses (MOOCs) (Scepanović, 2019).

The concept 'Education 4.0', as used in the academic literature discussed above, tends to be consistent with the use of its mother concept, namely the Fourth Industrial Revolution. There is little or no evidence to suggest any unique theoretical interpretation of the concept, when used in scientific contributions. However, the essence of the processes or practices that make up 'Education 4.0' give the concept a more complex meaning in the context of higher education transformation (Wessels, 2020).

Defining attributes of the concept 'Education 4.0'

The defining attributes of the concept, or the fourth step, identifies the traits most often associated with the concept and the phenomena to which it refers (Walker & Avant, 2014). As a result, this section moves beyond simply clarifying the concept by identifying its characteristics to a deeper understanding of the actual phenomenon to which it refers, which can aid in distinguishing the phenomenon under investigation (Education 4.0) from analogous or associated phenomena. The following have emerged as defining attributes of 'Education 4.0' within the framework of transformation of South African higher education, based on the generally agreed preliminary definition of the Fourth Industrial Revolution and as proposed in various literature on 'Education 4.0': fusion of technologies, multiplicity sites, non-discriminatory, lifelong learning, and student-centred emancipatory teaching and learning.

Fusion of technologies

'Education 4.0' makes teaching and learning a dynamic experience through the Fourth Industrial Revolution innovations such as 3D printing, multi-touch LCDs, cloud computing, virtual reality, holograms, augmented reality, biometrics, AI and QR codes (Butt *et al.,* 2020). In a study by Goh and Aris (2015), students described robotics as fascinating, enjoyable, smart, stimulating, and motivating. 'Education 4.0's artificial intelligence (AI) aims to 'think' like people, recalling or understanding dynamic patterns, interpreting data, and drawing conclusions (Naidoo & Singh-Pillay, 2020). 'Education 4.0', as a result of its emphasis on these innovations, aligns with the government's long-term goal of improving access, diversity, and quality through free and resource-based learning and the use of a variety of media, as stated in the *Education White Paper 3: A Programme for the Transformation of Higher Education.*

Multiplicity of Sites

'Education 4.0' allows students to find sources to develop new skills and knowledge (Hussin, 2018). Students decide when and how they study in 'Education 4.0', with the teacher serving as a facilitator. Ally and Wark (2020) used an analogy in which a server with a curriculum and learning management system may be mounted on unnamed aerial vehicles (UAVs, or "drones") to justify the importance of the Fourth Industrial Revolution technology in providing education to students regardless of their location and status. These technologies then encircle a remote location, allowing students to access learning materials via wireless mobile devices. This enables higher education institutions to offer education to students rather than the other way around (through physical schools). Such multiplicity sites will also allow student mobility and higher education internationalisation (Scepanovi, 2019).

Non-discriminatory

'Education 4.0' is ideally suited to improving South African higher education because of its potential to offer open learning options for all people, regardless of their status or location (Ally & Wark, 2020) as well as student mobility (Scepanovi, 2019). Its non-prejudice attribute aligns with a range of democratic-era laws, including the *Constitution of the Republic of South Africa Act 108 of 1996* and the *Promotion of Equality and Prevention of Unfair Discrimination Act 4 of 2000*, all of which aim to discourage unfair discrimination and encourage justice. Hence, the *National Plan for Higher Education,* in line with The *White Paper 3 on Higher Education Transformation* (1997) (Department of Education [DOE], 1997) and the subsequent *Education White Paper 6: Special Needs Education* (DOE, 2001), urged higher education institutions to make a pledge in their institutional plans to expand access for all students from all backgrounds.

Lifelong learning

Employers want staff who demonstrate innovation, teamwork, and entrepreneurial abilities, as well as the capacity to collaborate in interdisciplinary teams and integrate interdisciplinary expertise into their work, given the rapid developments associated with the Fourth Industrial Revolution technology (Fomunyam, 2019). 'Education 4.0' is becoming more important for upskilling and reskilling workers at all stages of their careers (Yusuf *et al*., 2020). As a result, 'Education 4.0' helps people to keep up to date with trends in the Fourth Industrial Revolution (Ally & Wark, 2020).

Student-centeredness and emancipatory teaching and learning

According to Butt *et al.* (2020), 'Education 4.0' allows students to think in unconventional ways in order to satisfy the demands of a modern diverse and rapidly changing world. This has been observed among the so-called Generation Z, also known as the do-it-yourself (DIY) generation, who think they can do anything on their own with the aid of YouTube, where thousands of video modules addressing almost any subject are available online (Reaves, 2019). The Hole in the Wall Project (Mitra, 2014) and its follow-up Hole in the Cloud, in which Mitra (2019) looks at approaches where students can use the Fourth Industrial Revolution technology to navigate study materials in the clouds, further demonstrating self-directed learning and students' capacity to learn on their own. Given the burgeoning availability of open educational resources (OERs), such a phenomenon is very likely. This is reaffirmed by Waghid *et al.* (2019) who argue for ruptured pedagogical activities in which teachers and students participate autonomously and deliberatively in pedagogic spaces as equals.

A model case of 'Education 4.0'

This step, according to Walker and Avant (2014), offers an example of the concept's usage that demonstrates its defining attributes. A model case is a real-world implementation of a concept (Maputle and Donavon, 2013). Therefore, such recognisable evidence of a scenario or model case, in which all of the distinguishing characteristics of the concept 'Education 4.0' are present, aids comprehension of the concept in question (Zongozzi, 2020b). Since this study explored 'Education 4.0' in the context of South African higher education transformation, it was relevant for the 'real-life' example or model case to provide such contextual conditions that are comparable to those in the country's transformation agenda, such as the need to restructure the curriculum, increase access, and enhance student performance. Hence, the following model case is appropriate:

Pong (1995) stated that, like South Africa, the Malaysian government had greater faith in the capacity of education to equalise community participation in the country's social and economic growth. Malaysia is renowned for being a multi-racial nation with strict preferential policies aimed at restructuring ethnic groups' socioeconomic roles. According to reports, Malaysian higher education has launched a Fourth Industrial Revolution-compliant 'Education 4.0' curriculum. Its aim is to equip graduates with the skills and knowledge that the digital-driven market requires. This started in 2016, when the country's government launched MOOCs, a flexible mode of learning aimed at creating a more globalised online learner. The online course seeks to encourage online and "...permanent learning pursuits among Malaysians through diversification of classroom experience and unlimited open access participation via online" (Lawrence, Ching and Abdullah, 2019, p.512). Accreditation in Prior Experiential Learning (APEL) was also adopted by the government for people with work experience but no qualifications. Furthermore, the *2u2i academic curriculum*, which is entirely focused on employment training, was implemented with the intention of integrating academic learning and industrial learning applications in the learning process. This programme, which aims to provide students with more realistic, industry-based learning in order to help prepare them for the future, includes two (2) years of study and two (2) years of industrial training.

The above is a model case since it exemplifies the attributes of 'Education 4.0'. A non-discriminatory approach to flexible and lifelong learning, through the use of web technology-aided MOOCs, is/was used in response to the government's need for equity and accessibility.

Related case of the concept 'Education 4.0'

A conceptual confusion stems from the use of a concept with borderline, related, contrary, invented, or illegitimate meanings (Zongozzi, 2020b). This happens when the concept 'Education 4.0' is used, yet includes either none of its defining attributes, or a few, but not all of them (Walker & Avant, 2014), causing semantic uncertainty (Zongozzi, 2020b). Maputle and Hiss (2013) regard related cases of a concept as instances that are similar to the concept, but on closer examination are quite different. While the Fourth Industrial Revolution builds on the digital revolution that has been happening since the middle of the last century, namely the Third Industrial Revolution (Ocholla & Ocholla, 2020), where electronics and information technology is used, Hussin (2018) observes that the Fourth Industrial Revolution is more than an improvement of the Third Industrial Revolution, in which the advancement of emerging technologies blurs the boundaries between the physical, digital, and biological realms. For instance, machines 'speak' with one another via the internet of things, processes respond to artificial intelligence created by algorithms, and human beings converse with mechanical processes in real time through bidirectional interfaces. This backs up Kayembe and Nel's (2016) assertion that the Fourth Industrial Revolution encompasses more than just smart technologies and computers. The Fourth Industrial Revolution is radically different from past revolutions because of the convergence of these systems and their integration through the physical, interactive, and biological realms.

Antecedents of 'Education 4.0'

Antecedents are those activities or occurrences or processes that should exist or be in effect prior to the occurrence of the concept, according to the concept analysis process (Walker & Avant, 2014). From this perspective, antecedents in this study refers to certain activities or processes that will contribute to the provision of 'Education 4.0' in the context of higher education transition in South Africa. The literature suggests the following antecedents are necessary towards transforming the country's higher education: research and discourse, policies, capacity building, and infrastructure development.

Research and discourse

Research and the other antecedents are inextricably linked. Evidence-based practice is essential for obtaining and translating high-quality scientific research evidence into the best practical decisions (Steglitz, Warnick, Hoffman, Johnston, & Spring, 2015). Research and discourse are inevitable antecedents as they could provide a good theoretical grounding for education policies. Inadequate prior research result in policies that are defective in their theoretical conception (Khan, 2016).

Transformative policies

Without relevant transformative policies, and the political will to effectively enact such policies, 'Education 4.0', and all of its attributes, will not be realised (Butt *et al*., 2020, p.173). South Africa has effective progressive education policies and strategies in place (see background and introduction section), which must be applied in tandem with the other antecedents in order to achieve 'Education 4.0'.

Infrastructure development

Inequality and income distribution are currently a challenge in South Africa (Kayembe & Nel, 2019,). The Fourth Industrial Revolution's disruptions, on the other hand, could have unforeseeable socio-

economic repercussions for Africa. Concerns have been raised that the Fourth Industrial Revolution, and thus 'Education 4.0', would exacerbate inequality in the country (Ravhudzulo, 2019). The biggest concern is the digital divide (Lourie, 2017), in which some parts of the population have access to information technology, allowing them to pursue better career and educational prospects, greater personal progression, and fuller access to social networks, while others do not (NGO Pulse, 2020). Infrastructure development such as Open Access Fibre, will thus assist South Africa through bridging this digital divide (Lourie, 2017). As a result, infrastructure development as a requirement will ensure equal access to quality education 4.0 for everyone, including rural and urban disadvantaged students, as well as students with disabilities, thus achieving the NDP targets and SDGs.

Capacity building

Naidoo and Singh-Pillay (2020) maintain that it is quintessential for educationalists and lecturers to keep abreast with new educational trends, pedagogies and their accompanying pedagogic tools in order to equip students with 21st Century skills. This will make these specialists aware of the demands and expectations this change will force on the education sector (Ally & Wark, 2020). While it is predicted that the lecturer's position in 'Education 4.0' will move to that of a coach, mentor, or facilitator, in which students in a flipped classroom respond to material already available online (Reaves, 2019), whichever case it may be, these individuals may need a range of core skills to face the challenges posed by the Fourth Industrial Revolution technologies. These include abilities (cognitive, logical reasoning, problem solving, creativity and mathematical reasoning), basic skills (information and communication technology (ICT) literacy, reading comprehension, oral and written expression, active listening, critical thinking and monitoring self and others), and cross-functional skills (social skills, technical skills, system skills, complex problem-solving skills, and resource management skills) (Yusuf *et al*., 2020, p.96).

Consequences of the concept 'Education 4.0'

Contrary to antecedents, the consequences of a concept are "those events or incidents that occur as a result of the occurrence of the concept" (Walker & Avant, 2014, p.173). Therefore, the outcomes from the model case illustrated above could be viewed as a consequence of the concept 'Education 4.0', as all of the concept's defining attributes appear to be present. According to the findings from the study reporting on the model case, 'Education 4.0' has the following implications, which can be divided into strengths and weaknesses (Lawrence, Ching, and Abdullah, 2019, p.515):

Strengths

- Creates an opportunity for all students and lecturers to engage in new technology tools. This involves the use, creation, manipulation and sharing of information on computer devices and over computer networks.
- Enhances the knowledge and usage of technology. Students and lecturers can learn and know how to operate and integrate the technology tools effectively.
- Development of technology classroom into the 21st Century Skills. Use of technology-based tools and resources to facilitate teaching and learning in a non-traditional way that allows students to learn on their own.

Weaknesses

Resistance to change. Lecturers may resist to step out from their comfort zone that they have been practicing for many years.

Digitally connected, social disconnection. While the fusion of technology would make information available at everyone's convenience at any time anywhere, it may lead to disconnect from the real-world and, by-so-doing, affect the interpersonal relationships amongst the people.

Table 1: Antecedents, defining attributes and consequences of "Education 4.0" within the context of transformation of higher education in South Africa.

Antecedents of the concept "Education 4.0"	Those events or incidents that must occur or be in place prior to the occurrence of the concept (Walker and Avant, 2014, p. 173).

- **Research and Discourse**
- **Transformative policies**
- **Infrastructure development**
- **Capacity building**

Defining attributes of the concept "Education 4.0"	Characteristics most often associated with the concept and the phenomenon to which it refers (Walker and Avant, 2014, p. 168).

- **Fusion of technologies**
- **Multiplicity of sites**
- **Non-discriminatory**
- **Lifelong learning**
- **Student-centeredness and emancipatory teaching and learning**

Consequences of the concept "Education 4.0"	Those events or incidents that occur as a result of the occurrence of the concept (Walker and Avant, 2014, p. 173).

Strengths

- Creates and opportunity for all students and lecturers to engage in new technology tools
- Enhances the knowledge and usage of technology
- Development of technology classroom into the 21st century skills

Weaknesses

- Resistance to change
- Digitally connected, socially disconnected

Define empirical referents for the concept 'Education 4.0'

This final step entails the identification of empirical referents or indicators to measure or validate the existence of the concept 'Education 4.0' in reality. These are the classes or categories of actual

phenomena that by their existence or presence demonstrate the occurrence of the concept itself. However, they are directly related to the defining attributes, but not directly to the concept itself, and can be used to measure the defining attributes and provide indirect evidence that demonstrates occurrence of the concept in a practice setting (Walker & Avant, 2013). Thus, it was important to remember the principles that underpin transformation in South Africa higher education. By virtue of observing the presence of these principles in education provision, it becomes certain that the concept 'Education 4.0' within the context of transformation has occurred. These principles include the Batho Pele principles, Ubuntu, United Nations Global Compact (UNGC) principles, and sustainable development principles.

Conclusion

'Education 4.0' could have significant implications towards progress on transforming the South African higher education. Based on its defining attributes of fusion of technology, multiplicity of sites, non-discriminatory, lifelong learning, and student centeredness, 'Education 4.0' could be the appropriate response to the government's long intended transformation, provided it is adequately articulated. To ensure this, an evidence-based practice through which high-quality scientific research, leading to the formulation of good policies, infrastructure development and capacity building should be prioritised. Thus, the framework provided in this study serves as a guide for understanding the necessary processes involved in designing an adequate 'Education 4.0' ecosystem if the government seeks to transform the South African higher education.

References

Adelabu, O. S., & Campbell, A. D. (2020). Appropriate knowledges: an exploration of South African industrial design curricula in the era of the Fourth Industrial Revolution. *International Conference on Engineering and Product Design Education* 10-11 September 2020, Via Design, Via University College, Herning, Henmark

Akoojee, S., & Nkomo, M. (2007). Access and quality in South African higher education: The twin the challenges of transformation. *South African Journal of Higher Education, 21(3)*:385–399

Ally, M., & Wark, N. (2020). *Sustainable Development and Education in the Fourth Industrial Revolution (the Fourth Industrial Revolution)*. Kingsway, Suite 2500, Burnaby: Commonwealth of Learning

Butler-Adam, J. 2018. The Fourth Industrial Revolution and education. *South African Journal of Science*, *114(5/6)*, 1 page. http://dx.doi.org/10.17159/ sajs.2018/a0271

Butt, R., Siddiqui, H., Soomro, R. A., & Asad, M.M. (2020). Integration of Industrial Revolution 4.0 and IOTs in academia: a state-of-the-art review on the concept of Education 4.0 in Pakistan. *Interactive Technology and Smart Education 17(4)*: 337-354.

Chabeli, M., & Muller, M. (2004). Reflective thinking in clinical nursing education: a concept analysis. *Curationis 27(4)*: 49–62.

Council on Higher Education. (2020). *Webinar on Advancing the Fourth Industrial Revolution within the Context of Transformation of Higher Education in South Africa*. 02 September 2020

Department of Education (DoE). (1997). *Education white paper 3: A programme for the transformation of higher education*. Pretoria: DoE

Department of Education (DoE). (2001). *Education white paper 6: Special needs education: Building an inclusive education and training system. Pretoria:* DoE

Department of Higher Education and Training. (2018). *Strategic policy framework on disability for the post-school education and training system*. Pretoria: Author. Available from: https://www.dhet.gov.za/SiteAssets/Gazettes/Approved%20Strategic%20Disability%20Policy%20Framework%20Layout220518.pdf [Accessed 02 March 2021]

Development Bank of South Africa. (2010). *Transformation in higher education: A briefing paper.* Available from: https://www.dhet.gov.za/summit/Docs/2010Docs/Transformation%20in%20higher%20education-%20A%20briefing%20paper%20by%20Crain%20Soudien.pdf (Accessed: 04 March 2021)

Engelbrecht, P. (2006). The implementation of inclusive education in South Africa after ten years of democracy. *European Journal of Psychology of Education*, *21*(3), 253–264. Retrieved from http://download.springer.com/static/pdf/625

Ghavifekr, S., & Rosdy, W. A. W. (2015). Teaching and learning with technology: Effectiveness of ICT integration in schools. *International Journal of Research in Education and Science (IJRES)*, 1(2): 175-191

Goh, H., & Aris, B. (2015). Using robotics in education: lessons learned and learning experiences.

1st International Malaysian Educational Technology Convention, 2015. Available [Online]:https://www.researchgate.net/publication/255604397_USING_ROBOTICS_IN_EDUCATION_LESSONS_LEARNED_AND_LEARNING_EXPERIENCES (Accessed: 12 March 2021)

Grinshkun, V,. & Sipovskaya, E. (2020). Teaching in the Fourth Industrial Revolution: Transition to Education 4.0. *Proceedings of the 4th International Conference on Informatization of Education and E-learning Methodology: Digital Technologies in Education (IEELM-DTE 2020)*, Krasnoyarsk, Russia, October 6-9, 2020

Gumede, V., & Biyase, M. (2016). Educational reforms and curriculum transformation in post-apartheid South Africa. *Environmental Economics* 7(2):69 – 76

Himmetoglu, B., Aydug, D., & Bayrak, C. (2020). Education 4.0: defining the teacher, the student, and the school manager aspects of the revolution. *Turkish Online Journal of Distance Education.* 2020, 21: 12–28

Hussin, A. A. (2018). Education 4.0 Made Simple: Ideas for Teaching. *International Journal of Education & Literacy Studies* 6(3): 92 – 98

Kayembe, C., & Nel, D. (2019). Challenges and Opportunities for Education in the Fourth Industrial Revolution. *African Journal of Public Affairs 11(3):* 79 – 94

Khan, R. (2016). Policy implementation: Some aspects and issues. *Journal of Community Positive Practices XVI (3)*: 3 – 12

Lawrence, R., Ching, L. F. & Abdullah, H. 2019. Strengths and Weaknesses of Education 4.0 in the Higher Education Institution. *International Journal of Innovative Technology and Exploring Engineering (IJITEE) 9(2S3)*: 511 – 519

Lee, Y., & Choi, J. (2011). A review of online course dropout research: Implications for practice and future research. *Education Tech Research Dev 59(2011)*: 593–618

Lourie, G. (2017). *Open Access Fibre Infrastructure: Can Help South Africa to Bridge the Digital Divide*. Available [Online]: https://www.techfinancials.co.za/2017/07/26/open-access-fibre-infrastructure-can-help-south-africa-to-bridge-the-digital-divide/ (Accessed: 14 March 2021)

Maputle, M.S. & Hiss D. 2013. Woman-centred care in childbirth: A concept analysis (Part1). *Curationis 36(1)*, 1 - 8. http://dx.doi.org/10.4102/ curationis. v36i1.49

Mhlanga, D., & Moloi, T. (2020). COVID-19, and the Digital Transformation of Education: What Are We Learning on the Fourth Industrial Revolution in South Africa? *Educ Sci 10(7)*: 1-11. https://doi.org/10.3390/educsci10070180

Ministry of Education. (2001). *National plan for higher education*. Pretoria: Ministry of Education

Mitra, S. (2014). The future of schooling: Children and learning at the edge of chaos. *Prospects 44(2014)*, 547–558. https://doi.org/10.1007/s11125-014-9327-9

Mitra, S. (2019). *The future of learning. Keynote speech presented at Pan- Commonwealth Forum 9 (PCF9)*, September 2019, Edinburgh, Scotland

Naidoo, J., & Singh-Pillay, A. (2020). Exploring Mathematics Teachers' Professional Development:

Embracing the Fourth Industrial Revolution. *Universal Journal of Educational Research 8(6)*: 2501-2508.

National Planning Commission. (2011). *National Development Plan 2030: Our future – make it work*. Available from: https://www.gov.za/sites/default/files/gcis_document/201409/ ndp-2030-our-future-make-it-workr.pdf (Accessed 02 March 2021)

NGO Pulse. (2020). Levels of Digital Divide in South Africa. Available [Online]: http://www.ngopulse.org/article/2020/08/28/levels-digital-divide-south-africa (Accessed: 14 March 2021)

Nkosi, T., Aboginije, A., Mashwama, N., & Thwala, W. (2020). Harnessing Fourth Industrial Revolution (the Fourth Industrial Revolution) for Improving Poor Universities Infrastructure in Developing Countries-A Review. *Proceedings of the International Conference on Industrial Engineering and Operations Management Dubai, UAE, March 10-12, 2020*

Ntshoe, I. (2011). The political economy of public-private good of open, distance, higher education institutions in South Africa. *Acta Academica*, *43*(3): 83–106

Ocholla, D. N., & Ocholla, L. (2020). Readiness of academic libraries in South Africa to research, teaching and learning support in the Fourth Industrial Revolution. *Library Management 41(6/7)*: 355-368

Oke, A., & Fernandes, F.A.P. (2020). Innovations in Teaching and Learning: Exploring the Perceptions of the Education Sector on the 4th Industrial Revolution (the Fourth Industrial Revolution). *Journal of Open Innovation: Technology, Market and Complexity,* 6(31): 1 – 22

Pandor, G. N. M. (2018). Contested meanings of transformation in higher education in post-apartheid South Africa. *Unpublished thesis*. Pretoria: University of Pretoria

Pong, S. (1995). Access to Education in Peninsular Malaysia: ethnicity, social class and gender. *Compare 25(3)*, 239-252. DOI: 10.1080/0305792950250305

Ravhudzulo, L. (2019). The Fourth Industrial Revolution deepening inequalities in South Africa. Unisa. https://www.unisa.ac.za/ sites/corporate/default/News-&-Media/Articles/the Fourth Industrial Revolution-deepening-inequalities-in-South-Africa (Accessed 14 March 2021).

Reaves, J. (2019). 21st-century skills and the fourth industrial revolution: A critical future role for online education. *International Journal on Innovations in Online Education 3(1)*: 1 – 21

Scepanović, S. (2019). The Fourth Industrial Revolution and Education. *The 8th Mediterranean Conference on Embedded Computing (meco)*, 10-14 June 2019. Budva, Montenegro

Schwab, K. (2017). *The Fourth Industrial Revolution*. New York: Currency Books

South Africa (Republic). (1996). *Constitution of South Africa Act 108 of 1996*. Pretoria: Government Printer

South Africa (Republic). (2000). *Promotion of Equality and Prevention of Unfair Discrimination Act 4 of 2000*. Pretoria: Government Printer

Steglitz, J., Warnick, J. L., Hoffman, S. A., Johnston, W., & Spring, B. (2015). Evidence-based practice. *International Encyclopaedia of the Social & Behavioural* Sciences 2nd edition (8): 332–338

Sun, Y., & Knobf, M. T. (2008). Concept analysis of symptom disclosure in the context of cancer. *Advances in Nursing Sci*ence *31(2008)*: 332–341

University of South Africa. (2018). *Open Distance e-Learning Policy.* Pretoria: Unisa. Available [Online]: https://staff.unisa.ac.za/sites/intranet/default/Policies/Teaching,-Learning-Community-Engagement-and-Student-Support (Accessed 19 July 2021)

Waghid, Y., Waghid, Z., & Waghid, F. (2019). The fourth industrial revolution reconsidered: on advancing cosmopolitan education. *South African Journal of Higher Education 33(6)*: 1–9.

Walker, L. O., & Avant, K. C. (2014). *Strategies for Theory Construction in Nursing. 5th edition*. Harlow: Pearson

Wessels, L. (2020). How South African universities can contribute to preparing the future workforce for the fourth industrial revolution. *Unpublished dissertation*. Stellenbosch: University of Stellenbosch

Wessels, J. S. (2020). Challenges to inform the curricula of Master of Public Administration programmes. *Teaching Public Administration 38(2)*: 144–167

Whalley, B., France, D., Park, J., Mauchline, A., & Welsh, K. (2021). Towards flexible personalized learning and the future educational system in the fourth industrial revolution in the wake of Covid-19. *Higher Education Pedagogies 6(1)*: 79-99

Yusuf, B., Walters, L. M., & Sailin, S.N. (2020). Restructuring Educational Institutions for Growth in the Fourth Industrial Revolution (the Fourth Industrial Revolution): A Systematic Review. *International Journal of Emerging Technologies in Learning* 15(3): 93 – 108

Zongozzi, J.N. (2020a). Accessible Quality Higher Education for Students with Disabilities in a South African Open Distance and e-Learning Institution: Challenges. *International Journal of Disability, Development and Education (2020),* 1 - 13. DOI: 10.1080/1034912X.2020.1822518

Zongozzi, J. N. (2020b). A concept analysis of theory in South African Open Distance and E-Learning research. *Open Learning: The Journal of Open, Distance and e-Learning (2020),* 1 – 15. DOI: 10.1080/02680513.2020.1743172

The Intricacies of the Fourth Industrial Revolution in Relation to Higher Education in South Africa

C.L. Obi

School of Science and Technology

Sefako Magkatho Health Sciences University

lawrence.obi@smu.ac.za

Abstract

The paper examines the state of higher education in South Africa in the era of the Fourth Industrial Revolution. It chronicles the current trends in curricula issues, mode of delivery, the need to re-engineer the curriculum, importance of cross-cutting skills and readiness of higher education for the Fourth Industrial Revolution. The Fourth Industrial Revolution is bound to have ripple effects on all sectors, especially education and the way knowledge is transmitted. Higher education should therefore customise training facilities and focus on producing graduates for the automation economy that is future ready. Upskilling and retraining are critical. A systematic approach involving holistic education systems, predicated on teaching students how to learn, instead of what to learn is also critical. The spirit of the Fourth Industrial Revolution is the ability to learn, unlearn and relearn. This means re-imagining the *modus operandi* of higher education in South Africa, including infrastructural and human capital development. Science-based, humanities and social sciences students should be knowledgeable about socio-political aspects of the world and the fundaments of artificial intelligence and applied sciences or the imperatives of the Fourth Industrial Revolution. The primary challenge associated with the Fourth Industrial Revolution for education is inequality which may exacerbate crime rates, gender-based violence, school dropouts and unemployment because the poor may be side-lined in terms of their ability to afford new technologies.

Keywords: Fourth Industrial Revolution, Higher Education, upskilling, artificial intelligence, inequality

Introduction

The Fourth Industrial Revolution is creating dynamic changes in all sectors across the world. It is about the digital revolution, anchored on the developments of the previous revolutions. It consists of the use of big data analytics, Internet of Things (IoTs), high-speed mobile internet, artificial Intelligence, cloud technology, gene sequencing, nanotechnology, renewables, quantum computing and automation. It is a major development that is bound to have ripple effects on education and the way knowledge is transmitted. The development calls for a re-engineering of the curriculum, upskilling, work-based and place-based learning, as well as massive infrastructural development.

The lop-sidedness of the educational landscape in South Africa as a result of historical antecedents has led to the existence of historically disadvantaged and under-resourced institutions as well as historically advantaged and well-resourced institutions. Furthermore, some students from disadvantaged communities are under-prepared to cope with the rigours of higher education and the dictates of the Fourth Industrial Revolution. Their poor background in mathematical, computing, information technology, communication and entrepreneurial skills are expectedly bound to affect their

preparedness for higher education within the context of the Fourth Industrial Revolution.

The scope of this paper includes the various industrial revolutions, higher education curriculum issues, impact of the Fourth Industrial Revolution on global society, higher education, evolution of education and employment, industrialisation and employment, and the perspectives of the educational landscape in South Africa. Conclusions and recommendations are presented to foreground overarching and critical aspects and to address the challenges identified respectively

Various industrial revolutions

An industrial revolution is one of the most significant developments in the world, traversing the use of electricity, telecommunications, machines, to various forms of new technologies. It is a key driver of government policies and affects socio-economic aspects of society (Stearns,2018; Kazembe and Nel, 2019). Indeed, it refers to the continuum of development events from pre-industrial to an industrial society, marked by economic growth (Vries, 2008, Chetty & Pather, 2015).

Three different industrial revolutions have taken place worldwide before the Fourth Industrial Revolution (Stearns, 2018). In delving into the intricacies of the Fourth Industrial Revolution, it is pertinent to first survey the nuances of the First, Second and Third Industrial Revolutions. The First Industrial Revolution started in the Middle Ages and probably ended in 1780 (Ionescu, 2018). It emerged through the use of water and steam power in catalysing different forms of agricultural production through mechanisation. Infrastructural development and manufacturing, exemplified by applications of steam engines to mining were other hallmarks of the First Industrial Revolution. Steam power was regarded as the foundation that linked the key roles of coal, iron, and cotton (Penphrase, 2017). It also witnessed the emergence of railways, increased communication, rise of banks, financing, and investments (Roberts 2015, Kayembe and Nel, 2019). The epicentre of the First Industrial Revolution was Britain. However, after the transformation of the British Empire, many European countries soon followed in the revolution and several countries transitioned from dark ages, lower-income households to rich countries (Roberts 2015; Kayembe, 2019). This development put European countries ahead of other regions of the world and it spanned the period between the 18th and 19th centuries.

The Second Industrial Revolution was anchored on the use of electricity to drive manufacturing technologies such as railroads, oil, and steel (Agarwal & Agarwal 2017; Lee *et al*., 2018). It was predicated on computerisation and web-based interconnectivity has had monumental beneficial effects on all sectors of human endeavours. The invention of electricity was pivotal to the use of machines and expansion of businesses.

The Third Industrial Revolution, which commenced in the mid-1900s was enhanced by innovations in manufacturing, distribution, and energy factors (Roberts, 2015). The development of nuclear power and increased use of electronics were major aspects of the Third Industrial Revolution which saw a narrowing of the gap between Europe and other parts of the world (Roberts, 2015; Kayembe and Nel, 2019). An important impact of the Third Industrial Revolution on higher education was that it is revolutionising online and the traditional face-to-face learning, with its effects on the widening of access to higher education (Oke & Fernandes, 2020). Online environments have changed the narratives of space, boundaries, and time, and impacted on the long-held dependence on social or physical interactions (Geiger, 2017; Gregorian, 2014).

The Fourth Industrial Revolution is about the digital revolution, premised on the developments of the previous revolutions. It is a major development that is bound to have ripple effects on all sectors, especially education and the way knowledge is transmitted. Its main features include the use of big data analytics, Internet of Things (IoT), high-speed mobile internet, artificial Intelligence, cloud technology, gene sequencing, nanotechnology, bioengineering, renewables, quantum computing and automation (Cameron *et al*., 2014; Schwab, 2016; Kurzweil, 2017; Alsedrah, 2017) Oke & Fernandes, 2020). It is characterised by the blurring of the physical, digital, and biological platforms, making it fundamentally different from the previous revolutions (De Saulles 2017; Schwab 2016, Butler-Adam, 2018). It is happening across all disciplines, sectors and other endeavours of life and has ushered a new phase of innovation and growth across countries (Schwab 2016).

Figure 1 reflects a historical timeline of the four industrial revolutions whilst Table 1 shows the education responses to the revolutions.

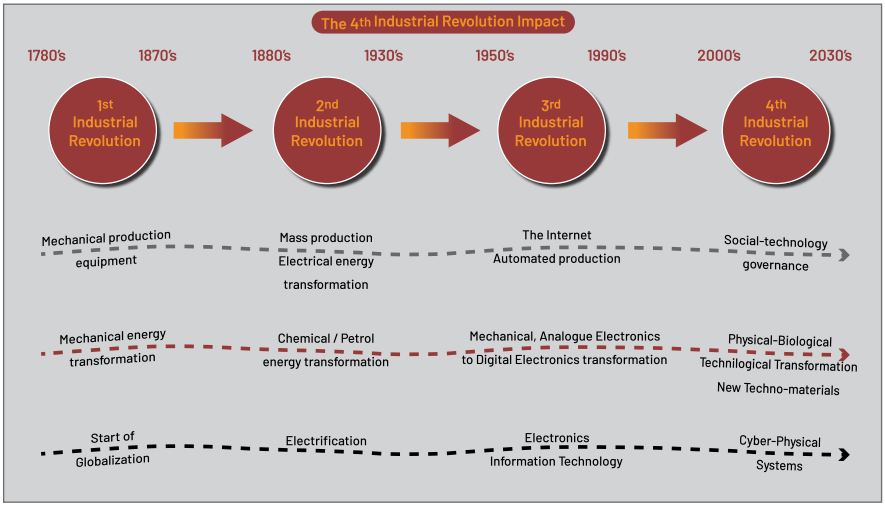

Figure 1: Historical timelines of the four industrial revolution

Source: Skilton and Hovsepian 2018

New norms such as implantable cell phones, digital presence, use of internet-connected clothes, robotic pharmacists, artificial intelligence auditors' artificial intelligence members of board of directors, transplantation of 3D printed organs, unimaginable sources of food production, may emerge in the era of the Fourth Industrial Revolution (Peters, 2017).

Table 1: Educational Response to industrial Revolution

Industrial revolution	Period	The description of educational curriculum
First Generation	In the early 1800s	This Industrial Revolution was originally intended to lead educational institutions into what is known as a New Education. It is a vision for a whole new kind of educational curriculum offering various degree options, as well as introducing novel educational programs.
Second Generation	1860 to 1900	Second Industrial Revolution was intended to make educational opportunity accessible for the industrial classes "sons of toil". It was intended to give birth to a "new economy" and to enable education that is "created for a steady stream of newly trained technicians and engineers trained in the practical avocations of life."
Third Generation	1980s to 1990s	The Third Industrial Revolution is fashioned around web-based technologies. This basically involves the internetwork of distributed systems for easy online access of information data. One of the biggest ripples from this era is the migration towards online education. In the year 2012, massive open online courses are expected to completely displace the traditional on-site educational systems, designated as the "Year of the MOOC." This extended access to university education to many people who previously were unable to take courses of interest or attend universities of choice. The Third Industrial Revolution has brought educators to an environment where access to information is immediate and free, shifting the focus toward active learning pedagogies that place a premium on collaboration within diverse teams in a project-based and peer learning environment.
Fourth Generation	2000s till date	The 4th Industrial Revolution often is described as the compounding product and multiple integrating effects of "exponential technologies", like artificial intelligence, computer networking technology, biotechnologies and nanomaterials. The best-known exponential technology is an "increase in computer power and decreasing cost in storage". However, substantial amendment will be made to the educational curriculum, allowing students to rapidly develop in emerging disciplines like artificial intelligence, robotics, genomics, data science and nanomaterials. 4IR STEM curriculum would still have to reconsider the traditional curriculum, like biology, chemistry and physics but in a different sphere or with a new perspective.

Source: *Gleason (2018)*

Higher Education curriculum issues

An urgent response from the higher education sector to these emerging technologies is warranted. The curriculum for science and technology should be tailored towards areas of genomics, robotics, data science, artificial intelligence, synthetic biology, molecular design, green chemistry (comprising chemistry, biology, and environmental science) and nanomaterials (Mammino & Vania, 2005; Drew,

2016; Kamal *et al*., 2018; Yusuf *et al*., 2020). Re-engineering of universities to offer science programmes in inter and multi-disciplinary areas is now warranted (Drew, 2016).

Strengthening blended or multi-modal learning will guarantee more flexibility for students' instruction but should be imbued with humanising pedagogy. The curriculum should aim to narrow the gaps due to these rapid and anticipated changes. The Liberal Arts should be strengthened (Godwin & Noah, 2017; Lewis & Rupp, 2016) to create the human touch (Lewis & Rupp, 2015; Anders 2017). The human aspects cannot be separated from advances in science and technology. Therefore, the Fourth Industrial Revolution curriculum should also tackle pertinent issues between humanities and science, technology, engineering, and mathematics (STEM) for a more effective, efficient, and integrated learning trajectory (Louis & Drew, 2015; Cyert, 2017). Essentially, some disciplines or professions need to rapidly customise training facilities to cope with the changes precipitated by the Fourth Industrial Revolution (Baygin *et al*., 2016). Speculations abound on the impact on the job market, as job losses are anticipated (Meyer & Gent, 2016; Nordin & Norman, 2018).

Germane to the above is the acquisition and upgrade of skills relevant to a workplace environment that is automated (Marsala, 2018). This means re-imagining the *modus operandi* of the educational system. The usual place-based learning, regurgitation of the contents of notes provided by lecturers or memorising textbook stuff may be superseded by cognitive, technical, reflective, adaptable and visionary competencies. The need to produce well-rounded graduates therefore comes to the fore (Badat, 2010). Science based, humanities and social sciences students should be knowledgeable about socio-political aspects of the world, the fundaments of artificial intelligence and applied sciences (Oke & Fernandes, 2020; Marsala, 2014; Marwala, 2018).

Equipping people with the skills for lifelong learning may address the challenges that may be occasioned by technological unemployment. The education system should be geared towards producing graduates for the automation economy that is future ready (Gleason, 2018). Automation is an offspring of advances in technology, exemplified by advances in big data, cloud computing, and machine learning (Gleason 2018). The trajectory will change what it means to be human due to access to humongous quantum of data that may catalyse generation of new knowledge, including innovative use of machines. It is anticipated that new jobs will be created but the likelihood of economic growth without job growth is on the immediate horizon (Roberts, 2015; Stearns, 2018). A systematic approach involving holistic education systems, predicated on teaching students how to learn, instead of what to learn for the purpose of entrenching an education system that is relevant and appropriate to the needs of the economy and society is critical (Brown, 2015; Lie & Stephen, 2019).

A system for graduates to constantly liaise with their institutions will be ultimately beneficial to workers, existing students, and academics in terms of being attuned with changing technological advancements in the workplace and academia. Another viable model is the 'open loop university', an extended duration of higher education that allows students to interlace their learning with life experience and occasionally ploughing back by returning as expert practitioners over designated periods in a bid to ensure cross-fertilization of knowledge (Stanford, 2013).

Figure 2 illustrates the characteristics and components of the technology involved in the Fourth Industrial Revolution.

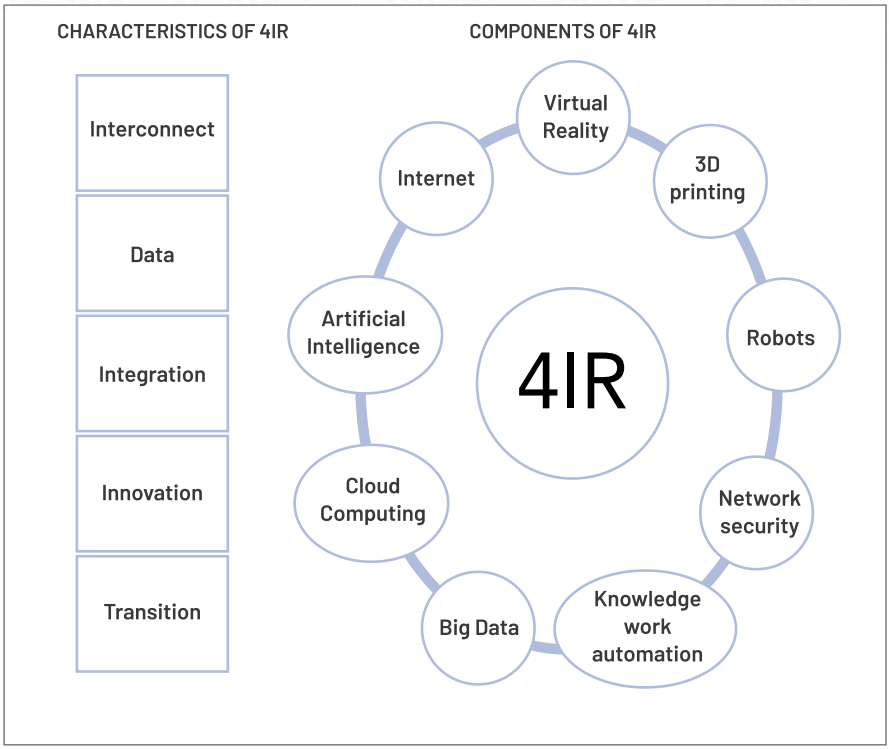

Figure 2: Characteristics and Components of Fourth Industrial Revolution Technology

Source: *Selamat et al ., 2017*

What the Fourth Industrial Revolution means for Higher Education

To match the paradigm shift, due to the Fourth Industrial Revolution, the usual placed based, face-to-face learning may be antithetic to a viable and dynamic form of education to guarantee employment and a rewarding career (Chetty & Pather, 2015). Consequently, the next question is how do we re-engineer the educational system in South Africa? Researchers have contended that education in its traditional form will be inadequate to tackle the hydra headed challenges of technological unemployment and that liberal arts education may be pivotal to producing future-ready graduates (Peters, 2017; Lewis & Rupp, 2015). Future employability may be premised on adaptive, flexible minds and cognitive agility to cope with the changes. A notable aspect of the Fourth Industrial Revolution is the liquid workforce, anchored on adaptation organised around projects, complemented with embedded training as opposed to the silo disposition, tailored towards specific roles or functions (Accenture, 2017). A new way of educating people is therefore warranted.

According to Gleason (2018), traditional institutions of higher education are still important, but their collaborative endeavours with governments should be strengthened. Funding channels from industry will give impetus to this narrative. This will not invalidate their autonomy or freedom to formulate

research and curricula agendas. Universities should be exemplary 'entrepreneurial ecosystems', where the skills of ideation, large-frame pattern recognition, creativity and complex communication holds sway (Brynjolfsson & McAfee, 2015; Aoun, 2017). However, it is important to note that people learn in different ways, at times influenced by cultures, and educators understand concepts from different perspectives. The traditional method in which lecturers transfer knowledge to several students seated in lecture rooms, who then absorb the information through memorisation, will not deliver the skills required for the age of artificial intelligence or for automation (Brown, 2015; Sung *et al*., 2016).

The research undertaken by Chang (2016) found that using a blended learning approach increased learners' satisfaction and performance by about 15% compared to only the classroom teaching approach. Similarly, Beetham and Sharpe (2013) reported that digital technology-facilitated interactions between tutors and learners and also complemented and re-invigorated the teaching and learning process. However, the use of technology in the education sector is rather low due to its perceived cost, training needs and operations (Mahlangu, 2020; Agarwal & Agarwal, 2017). Manasia *et al*., (2020) had reservations about the pedagogical, ethical, and epistemological aspects of technology in the education trajectory due to the teething challenges confronting full digitisation. The implications of the Fourth Industrial Revolution concerning moral and ethical decisions should not be underestimated (Kayembe & Nel, 2019; Hooker & Kim, 2019).

A workable pedagogy should be student-centred with students working in groups to find solutions to problematised situations. This is the nicety of problem based or project-based learning. They galvanise students to be more enthusiastic, motivated, focused and engaged in terms of disciplinary, inter-disciplinary and trans-disciplinary enterprises (Meyer & Gent, 2016).

The trump cards to pedagogical approaches in the era of the Fourth Industrial Revolution are problem-based learning, project-based learning, and experiential learning. They are termed self-organising environments (Brynjolfsson & McAfee 2014). For example, the pedagogy should be such that science students are taught to employ abstract scientific concepts to solve or explain or shed more light on complicated issues whereas mathematics students should cultivate the skills of advanced numerical and imaginative insights into complex situations. In liberal arts, students are imbued with the skills to discern grossly entrenched information from a data set, text, or graphics (Alsedrah, 2017; Butler-Adams, 2018).

Experience on the balance of higher education and the Fourth Industrial Revolution can be gleaned from Singapore, one of the economic power houses in Asia. Their strategy is hinged on three pillars, namely to 'deepen and diversify international connections, acquire and utilise deep skills, build strong digital capabilities" (Ng, 2011; Gleason, 2018). The first education strategy, 'Deepening and Diversifying International Connections', is executed in conjunction with the Global Innovation Alliance (GIA), to enhance innovation among youths. Entrepreneurial skills are forged between Singapore's universities and renowned innovation hubs worldwide in collaborative endeavours with oversees partners located in New York, Lausanne, Shanghai, Israel and China, Silicon Valley, Stockholm as well as Singapore (Gleason, 2018). Analogous to the above strategy is the 'Skills Future Leadership Development Initiative (LDI)', involving exposure of identified potential corporate moguls to state-of-the-art, high-quality opportunities to acquire knowledge of regional and international markets. Related to the 'Skills Future Leadership Development Initiative' is the 'Acquire and Utilise Deep Skills' programme (Ministry of Communications and Information Singapore, "Report of the Committee on the Future Economy:",

2017). Such deep skills include teamwork abilities, analytical skills, immense problem-solving skills and other skills that cultivate value, based on cognitive flexibility, to pave the way to ease into a rapidly evolving and changing digital ecosystem (Ng, 2011, Lee *et al*., 2018).

Building strong digital capabilities involves creating competencies in data analytics and cybersecurity (Peters, 2017). Computational thinking, namely statistics and programming, has been identified as a compulsory course for students in all disciplines at the National University of Singapore. Residential experience lends weight to this initiative as it fosters learning outside the classroom, a catalyst for lifelong learning skills as the approach involves regular interactions inside and outside the classroom. Experiential learning and international experience are built into the trajectory of learning, known as Learning Across Boundaries (LABs), including research attachments in reputable laboratories (Peters, 2017).

The higher education environment should be supported by digital skills, the Internet of Things (IoT), Wi-Fi-enabled network accessible to all students on different campuses (Lie & Stephen, 2019; Skilton & Hovsepian, 2018; Lee *et al*., 2018; Marshal, 2018). Digital skills refer to the appropriate and effective use of digital instruments to enhance communication and generate new knowledge access through synthesis, analysis, imagination, to give effect to beneficial social order (Skilton & Hovsepian, 2018; Lee *et al*.,2018; Marshal, 2018; Perez *et al*. 2018).

Figure 3 below indicates the various skills required in the era of the Fourth Industrial Revolution. They comprise abilities (cognitive and physical), basic skills (content and process) and cross functional skills (social, system, technical, complex problem solving and resource management skills (World Economic Forum, 2016; Yusuf et al., 2020).

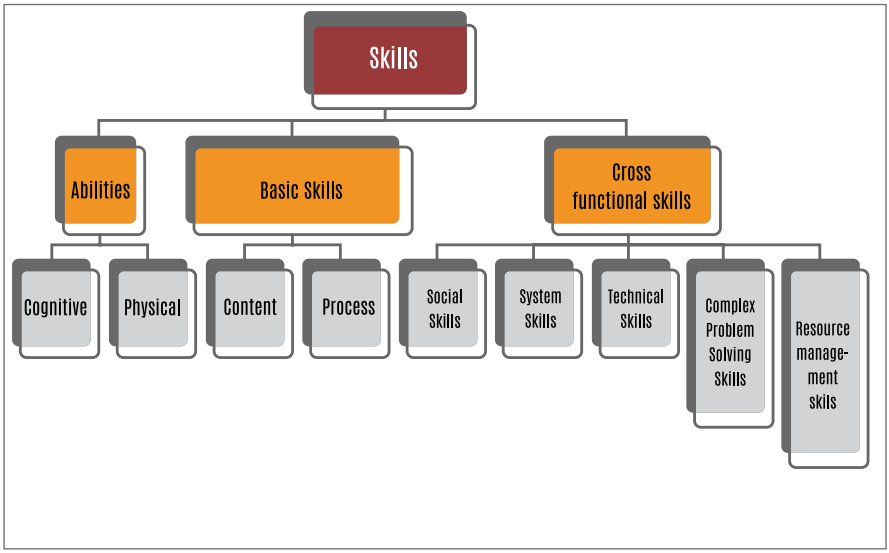

Figure 3: Core Skills needed in 4IR

Source: *World Economic Forum, 2016*

Opening up new opportunities

To cope with the dictates of the Fourth Industrial Revolution, schools should re-orientate towards equipping learners with the right skills to tackle present and future societal challenges, either as self-employed or employees of organisations/parastatals. Consequently, it is mandatory for teachers to continuously upskill to keep up with the anticipated changes in the curriculum. Providing access to internet and broadband, lowering data cost as well as partnerships involving government, private sector and civil society are stark realities for staff and students (Oke & Fernandes, 2020; Xing & Marwala, 2020). A reconfiguration of the current perception of education, employment and entrepreneurship can play a critical role in allowing people to build successful careers and businesses that are augmented and not threatened by these new technologies due to high ethical standards (Rojewski & Hill ,2017).

The evolution of higher education

The history of higher education is such that it has metamorphosed from the elite to mass and post massification, but the main functions remain teaching and learning, research, and community engagement (Xing & Marwala, 2014; Xing & Marwala, 2020). Traditionally, education has been somewhat disciplinary, leading to qualifications in a more focused and narrow area of specialisation, exemplified by the economic income between a general legal practitioner and a specialized legal practitioner.

The Fourth Industrial Revolution promotes interdisciplinary and T-shaped person - that is, someone who exudes a deep- seated knowledge of a specific field as well as adequate knowledge of fields outside their own specialisation (Oke and Fernandes, 2020). The skills obtained outside their area of specialisation offers a broader horizon of knowledge to navigate challenges.

How an evolution in education can transform employment

A noteworthy observation is that the Fourth Industrial Revolution has propelled skill development to be a seamless and accessible process. Search engines like Google, massive open online courses (MOOCs) and YouTube videos, have made a repertoire of knowledge readily accessible (Gwata, 2019).

A key point to note at this juncture is that technology does not make people obsolete, it can change the prerequisite for employment, leading to a requirement for an adequate level of computer literacy and competence.

Perspectives of the Educational Landscape in South Africa Within the Context of the Fourth Industrial Revolution.

The *multum in parvo* of challenges in the educational sector in terms of the Fourth Industrial Revolution are enormous and urgent steps are needed to give impetus to the apparent unpreparedness for the Fourth Industrial Revolution. The paucity of computers in primary and high schools imply very limited access to the use of computers at the designated schools, despite the key significance of computer skills in the Fourth Industrial Revolution (Lee *et al.*, 2018; Marshal, 2018). In some cases, students are admitted into higher education institutions without prior interactions with computers, even at Grade 12 level (Khathu, 2019). Internet access, power outages, connectivity challenges and data cost are militating factors to the maximisation of the potentials of the Fourth Industrial Revolution.

Teachers at primary and secondary schools have not been capacitated to withstand the impending

and ongoing wave of changes, especially against the backdrop of the skewed historical antecedents, mirrored by the state-of-affairs in urban, rural, and suburban schools (Khathu, 2019). In the higher education sector, data and information on the efficiency, effectiveness, and challenges of the use of technology are very limited (Bayne, 2015; Henderson *et al*., 2017; Manasia *et al*., 2020). Re-engineering or aligning curricula offerings in higher educational institutions is still at the seminal stages. Integration or infusion of entrepreneurial skills in school curriculum appears to be a mirage ambition. Entrepreneurship is shifting towards a low risk, high-return game versus a high-risk, low-return environment (Khathu, 2019). The act of writing computer programs (coding) has received a cursory attention in the curriculum, in spite of its importance for employment during the Fourth Industrial Revolution. Coding is critical for technical and non-technical disciplines (Khathu,2019).

The spirit of the Fourth Industrial Revolution is the ability to learn, unlearn and relearn (Toffler & Shock, 1970). The Covid-19 has in essence accentuated the transformation of the education sector in South Africa as social distancing and online learning have somewhat blighted the norms of face-to-face learning and other sectors (Mhlanga & Moloi, 2020; Mhlanga & Ndhlovu, 2020). It is similar to the manner of revolutionising social interactions through the use of Facebook, WhatsApp and Twitter (Famunyan, 2019).

According to Rüßmann *et al*., (2015), digital innovation is anchored on the following: cybersecurity, simulation, autonomous robots, internet of things, horizontal and vertical system integration, cloud, big data analytics, quantum computing, additive manufacturing, and augmented reality (Taylor-Sakyi, 2016; Alsedrah, 2017; Lee *et al*., 2018). The Fourth Industrial Revolution is not limited to computer usage but involves the development of an ecosystem that enhances exchange of learning materials and data analytics.

The need for South Africa to invest in internet of things (IoTs), algorithm and data analytics, using the Fourth Industrial Revolution as a springboard and customising teaching and learning to the needs of students may be a noteworthy approach (Brown, 2015; Henderson *et al*., 2017). Teachers may no more exhibit monopoly of knowledge but should be educators who chaperone and guide students to fortify their understanding of different concepts. The Fourth Industrial Revolution in the education sector is modelled after the World Economic Forum. It is explained as the juxtaposition of human and technology enabled operations that are invariably eroding the divides of the physical, digital, and biological worlds with monumental outcomes in various disciplines (World Economic Forum, 2016; Tymon, 2013; Garca-Penalvo, 2018, Oke & Fernandes, 2020).

Although technology has had significant impact on learners' development (Kreijns, 2013), researchers have posited that academic institutions are not listed in the top 50 leading innovative companies globally and none of the listed organisations is from Africa (Ringel *et al*., 2020).

Drawbacks of the Fourth Industrial Revolution for Higher Education

The Fourth Industrial Revolution has its drawbacks that are linked to the development and use of new technologies (Kayembe & Nel, 2019). These require appropriate risk management policy and systems to ensure successful harnessing of the human benefits of the Fourth Industrial Revolution (Kayembe & Nel, 2019). The potential of the Fourth Industrial Revolution to transform life in a positive way may be matched with the negative impacts of the consequent advances in science and technology (Kayembe & Nel, 2019).

The primary challenge of the Fourth Industrial Revolution for education is inequality (Kayembe & Nel, 2019). They posited that inequality and income distribution are major social issues which may fan high crime rates, gender violence, school dropouts and unemployment, among others. The education sector is already replete with inequality and may be exacerbated by the effects of the Fourth Industrial Revolution or new technologies as the poor are likely to be side-lined in terms of their ability to afford new technologies for higher education, as experienced during other revolutions (Kayembe & Nel, 2019).

A substantial proportion of the population of the country does not have access to electricity, transport, potable water supply and internet connectivity. This situation will ultimately catalyse civil insurrection due to the widened gap between the rich and poor. Therefore, strategies to manage the potential tension between the rich and poor, possibly due to advances in technology, differences in economic power and culture, should be entrenched (Penprase 2018; Kayembe and Nel, 2019).

Impacts of the Fourth Industrial Revolution on Global Society

Revolutions of the second and third industrial phases, marked by the use of computers in the workplace created anxieties or fear in different settings, a development aptly named computerphobia. This notwithstanding, such computerisation and automation paved the way for the establishment of new business concerns such as industries, with ripple effects on employment (Gwata, 2018). Entrepreneurial and intrapreneurial skills may be the trump card for employment. This term "intrapreneur" describes a person who is employed by another employer but deeply cultivates the spirit of being innovative (Gwata, 2018).

The Fourth Industrial Revolution is rooted in cyber-physical systems (CPSs) and is performing some human functions. CPSs are computer-based systems, facilitated by in-built computers and networks monitor in a feedback mechanism, with one informing or reinforcing the other. Functions such as the use of lawn mowers, loading of trucks, assembling of car parts during the manufacturing processes, driving cars, drug manufacturing are no longer exclusively human jobs (Gleason, 2018). The significance of these developments cannot be underestimated.

Previously, human beings had relied on machines to make core human labour more productive but with the Fourth Industrial Revolution, the possibility that human beings may no longer be needed for production, in any form, in future, is an apparent reality (Baygin *et al*., 2016). However, it is difficult to completely alienate human functions from the trappings of the Fourth Industrial Revolution because it is underpinned by the creativity of human beings. Human beings will work alongside robots, some claim as "cobots", and together they will amplify what is possible (Gleason, 2018).

Conclusion

It is concluded that the present mode of delivery of curricular offerings across most universities indicate that the South African Higher Education is not fully prepared for the Fourth Industrial Revolution. The traditional teaching and learning trajectory including disciplinary focus, place-based learning, lack of entrepreneurial education, lack of infrastructure and inadequate funding, attest to this assertion**.** Science- based, humanities and social sciences students are not knowledgeable about socio-political aspects of the world and the fundaments of artificial intelligence and applied sciences. Consequently, it is critical for South Africa to re-orientate students, re-engineer the curriculum, liaise with industry

and embrace the spirit of the rapid changes in science and technology in a bid to stay relevant to the ripple effects of the fourth industrial revolution. Re-imagining the *modus operandi* of the educational system has not taken place on a national scale. These drawbacks or challenges require appropriate risk management policy and systems to ensure higher education benefits from the Fourth Industrial Revolution.

Innovative teaching and learning strategies as well as curriculum re-engineering should be adopted to catch up with the momentum of the Fourth Industrial Revolution. Customised training facilities should be implemented for some disciplines and professions.

References

Accenture, P (2016). "Liquid Workforce: Building the workforce for today's digital demands" https://www.accenture.com/fr-fr/_acnmedia/PDF-2/Accenture-Liquid-Workforce-Technology-Vision-2016-france.pdf

Adekunle, O., & Fernandes, F. (2020). Innovations in Teaching and Learning: Exploring the Perceptions of the Education Sector on the 4thIndustrial Revolution (the Fourth Industrial Revolution). *Journal of Open Innovation: Technology, Markets and Complexity*, 6: 31

Agarwal, H., & Agarwal, R. (2017). First Industrial Revolution and Second Industrial Revolution: Technological differences and the differences in banking and financing of the firms. *Saudi Journal of Humanities and Social Sciences*, 2(11): 1062–1066

Alsedra, M.K. (2017). *Artificial Intelligence*. Kuwait: American University of the Middle East

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M.K. (2010). *How Learning Works: 7 Research-based Principles for Smart Teaching*. San Francisco, John Wiley & Sons

Aoun, R. (2017). *Higher Education in the Age of Artificial Intelligence*. Cambridge: MIT Press, 69

Badat, S. (2010). *The Challenges of Transformation in Higher Education and Training Institutions in South Africa*. Midrand: Development Bank of Southern Africa

Baygin, M., Yetis, H., Karakose, M., & Akin, E. (2016). An Effect Analysis of Industry 4.0 to Higher Education. In Proceedings of the 2016 15th International Conference on Information Technology Based Higher Education and Training (ITHET), Istanbul, Turkey, 8–10 September: 1–4

Bayne, S. (2015) What's the matter with 'technology-enhanced learning'? *Media Technol*. 40: 5–20

Beetham, H., & Sharpe, R. (2013) *Rethinking Pedagogy for a Digital Age: Designing for 21st Century Learning*. Routledge: Apollon, UK, 2013

Brynjolfsson, E., & McAfee, A. (2014) *The Second Machine Age*. New York: W. W. Norton, pp 12

Bucciarelli, L., & Drew, D. (2015) Liberal Studies in engineering: A design plan. *Engineering Studies* 7, Vol 2–3: 103–122

Butler-Adam, J. (2018). The Fourth Industrial Revolution and education. *South African Journal of Science*, 114(5/6):1–2

Brown, J. (2015) Complexities of digital technology use and the teaching and learning of function. *Computer Education*, 87: 112–122

Cameron, D., Bashor, C., & Collins, J. (2014) A brief history of synthetic biology. *Nature Reviews in Microbiology* 12: 381–390

Chang, V. (2016). Review and discussion: E-learning for academia and industry. *International Journal of Information Management* 36: 476–485.

Chetty, R., & Pather, S. (2015). Challenges in higher education in South Africa. In Condy, J. (Ed.). *Telling Stories Differently: Engaging 21st Century Students Through Digital Storytelling*. Stellenbosch: SUN MeDIA.

Choy, C., Sedhu, D., Liew, Y., Lee, Y., Malenee, A., & Anuar, N. (2015). Influence of Culture on Students' Awareness of How and Why They Learn. *Malaysian Journal of Learning and Instruction* 12: 49–67

Collins, A., & Halverson, R. (2018). *Rethinking Education in the Age of Technology: The Digital Revolution and Schooling in America*. New York: Teachers College Press

Cyert, M. (2017). Developing a New Introductory Biology Curriculum. Accessed November 2, https://vptl.stanford.edu/spotlight/developing-newintroductory-biology-curriculum.

De Saulles, M. (2017). *The Internet of Things and Business*. New York: Routledge

Drew. E. (2016). Yale-NUS College STEM Innovation Conference. April 27, http://steminnovation.sg/wp-content/uploads/2017/06/Endy_Yale_ NUS_STEM

Fomunyam, G. (2019). Education and the Fourth Industrial Revolution: Challenges and Possibilities for Engineering. *International Journal of Mechanical Engineering and Technology* (IJMET), 10 (08): 271– 284

Garca-Peñalvo, F., Fidalgo-Blanco, A., & Sein-Echaluce, M. (2018). An adaptive hybrid MOOC model: Disrupting the MOOC concept in higher education. *Telematic Information*. 35: 1018–1030

Geiger, R. (2017). *The Land-Grant Colleges and the Reshaping of American Higher Education*. New York: Routledge

Anders, G. (2017). *You Can Do Anything: The Surprising Power of a "Useless" Liberal Arts Education*. New York: Little, Brown and Company

Gleason, N. (2018). Singapore's Higher Education Systems in the Era of the Fourth Industrial Revolution: Preparing Lifelong Learners. In: *Higher Education in the Era of the Fourth Industrial Revolution* pp 145-169 Springer

Godwin, K., & Pickus, N. (2017). Liberal Arts and Sciences Innovation in China: Six Recommendations to Shape the Future. CIHE Perspectives, November 1. https://www.bc.edu/content/dam/files/research_sites/cihe/pubs/ CIHE%20Perspective/CIHE%20Perspectives%208_ENGLISH_13NOV2017.pdf.

Henderson, M., Selwyn, N., & Aston, R. (2017). What works and why? Student perceptions of 'useful' digital technology in university teaching and learning. *Stud. High Educ.* 42:1567–1579

Hooker, J., & Kim, T.W. (2019). Ethical implications of the 4th Industrial Revolution for business and society. In Wasieleski, D.M. and Weber, J. (Eds.). *Business Ethics (Business and Society 360,* Vol. 3. Bingley: Emerald Publishing Limited

Ionescu, I. (2018). The First Industrial Revolution and general features of the world economy between the 16th century and 1780. *SEA – Practical Application of Science.* 6(17):183–186

Jandric, P. (2017). From Anthropocentric Humanism to Critical Post humanism in Digital Education. In *Learning in the Age of Digital Reason*. Rotterdam, Sense Publishers: 195–210.

Johal, W., Castellano, G., Tanaka, F., & Okita, S. (2018). Robots for learning. *International Journal of Social Robotics* 10: 293–294

Mok, K. (2008). Singapore's global education hub ambitions: University governance change and transnational higher education. *International Journal of Educational Management* 22 (6):527–546

Kamal, N., Saad, M., Kok, C., & Hussain, A. (2018). Towards revolutionizing stem education via IoT and block chain technology. *International Journal of Engineering Technology* 7:189–192

Kayembe, C., & Nel, S. (2019). Challenges and Opportunities for Education in the Fourth Industrial Revolution. *African Journal of Public Affairs* 11 (3): 79-94

Kreijns, F., Van Acker, M., Vermeulen, M., & Buuren, H. (2013). What stimulates teachers to integrate ICT in their pedagogical practices? The use of digital learning materials in education. *Computers in Human Behaviour*. 29 (1): 217-225

Kurzweil, R. (2017). The Singularity is Near. New York: Penguin, 2005. LACOL. *Liberal Arts Consortium for Online Learning*. July 1, 2017. http:// lacol.net/

Lamprini, K., & Bröchler, R. (2018). How collaborative innovation and technology in educational ecosystem can meet the challenges raised by the 4th industrial revolution. *World Technopolis Review* 7: 2–14

Lee, M., Yun, J.J., Pyka, A., Won, D., Kodama, F., Schiuma, G., Park, H., Jeon, J., Park, K., Jung, K., Yan, M., Lee, S., & Zhao, X. (2018). How to respond to the Fourth Industrial Revolution, or the Second Information Technology Revolution? Dynamic new combinations between technology, market, and society through open innovation**.** *Journal of Open Innovation*, 4 (21) :1–24

Lewis, P., & Rupp, K. (2015). Liberal Education in Asia: Trends, Challenges, and Opportunities. *New Global Studies* 9 (3): 245–266

Liu, Z., & Stephen, V. (2019). Exploring innovation ecosystem from the perspective of sustainability: towards a conceptual framework. *Journal of Open Innovation and Technology*. Mark Complex 5: 48

Mammino, L., & Zunin, V. (2009). *Worldwide Trends in Green Chemistry Education*. Cambridge: Royal Society of Chemistry

Mazur, E. (2015). Farewell, Lecture? *Science* 323, no. 5910: 50–51

Manasia, L., Lanos, M., & Chicioreanu, D. (2020). Pre-service teacher preparedness for fostering education for sustainable development: An empirical analysis of central dimensions of teaching readiness. Sustainability (Switzerland), 12(1), 4–6. https://doi.org/10.3390/SU12010166

Marlin, D. M. (2018). This is how artificial intelligence will impact your job for better and worse. Forbes. 2018 January 16 [cited 2018 May 03]. Available from: https://www.forbes.com/sites/danielmarlin/2018/01/16/millennials-this-is-how-artificial-intelligence-will-impact-your-job-for-better-and-worse/#164ba5e44533

Marshall, S. (2016). Technological innovation of higher education in New Zealand: A wicked problem? *Studies in Higher Education*, 41(2): 288–301

Marwala, T. (2014) *Artificial intelligence techniques for rational decision making*. New York: Springer International Publishing

Marwala, T. (2018). Tackling bias in technology requires a new form of activism. Available from: https://

www.uj.ac.za/newandevents/Pages/Opinion-Tackling-bias-in-technology-requires-a-new-form-of-activism.aspx

Meyer, I.A., & Gent, P.R. (2016). *The Status of ICT in Education in South Africa and the Way Forward*. Centurion: The National Education Collaboration Trust (NECT). Available at: http://nect.org.za/publications/technical-reports/the-state-of-ict-in-education-in-south-africa.

Mhlanga, D., & Moloi, T. (2020). COVID-19 and the Digital Transformation of Education: What Are We Learning on the Fourth Industrial Revolution in South Africa? *Education Sciences*, 10(7): 180. https://doi.org/10.3390/educsci10070180

Ministry of Communications and Information Singapore (2017). *Report of the Committee on the Future Economy*.

Ng'ambi, D., Brown, C., Bozalek, V., Gachago, D., & Wood, D. (2016). Technology enhanced teaching and learning in South African higher education–A review of a 20-year journey. *British Journal of Education Technology*, 47: 843–858

Ng, P. (2011). Singapore's response to the global war for talent: Politics and education. International Journal of Educational Development 31(3): 262 - 268

Nordin, N., & Norman, H. (2018). Mapping the Fourth Industrial Revolution global transformations on 21st century education in the context of sustainable development. *Journal of Sustainable Development Education and Research*, 2(1):1 - 7.

Park, A. (2018). Study on the Changes of Libraries and Directions of Librarian Education in the era of the Fourth Industrial Revolution. *J. Korean Soc. Libr. Inform. Sci.* 52: 285 - 311.

Perez, J.A., Deligianni, F., Ravi, D., & Yang, G.Z. (2018). *Artificial Intelligence and Robotics*. London: UK-RAS Network

Lewis, P., & Rupp, K. (2015). Liberal Education in Asia: Trends, Challenges, and Opportunities. *New Global Studies*. 9(3): 245 - 266.

Peters, M., (2017). Technological Unemployment: Educating for the Fourth Industrial Revolution. *Journal of Self-Governance and Management Economics* 5(1): 28.

Ramukumba, K. (2017). The Fourth Industrial Revolution and the South African education system. Education News South Africa

Rashid, T., & Asghar, H. (2016). Technology use, self-directed learning, student engagement and academic performance: Examining the Interrelations. *Comput. Hum. Behav*, 63: 604–612.

Ringel, M., Zablit, H., Grassl, F., Manly, J., & Möller, C. (2018). *The Most Innovative Companies in 2018: Innovators Go All in on Digital*. The Boston Consulting Group: Boston, UK, Volume 28: 1–18

Roberts, B.H., (2015). *The Third Industrial Revolution: Implications for Planning Cities and Regions*. Urban Frontiers Working Paper. Tudun Wada: Urban Frontiers

Rojewski, J., & Hill, R. (2017). A Framework for 21st-century career-technical and workforce education curricula. *Peabody Journal of Education* 92 (2):180-191

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*. Boston Consulting Group: Boston, MA, USA, Volume 9, pp. 54–89. Macmillan: London, UK.

Saini, C.; & Abraham, J. (2019). Implementing Facebook-based instructional approach in pre-service teacher education: An empirical investigation. *Computer Education* 128: 243–255

Schwab, K. (2016). *The Fourth Industrial Revolution*. Geneva: World Economic Forum

Selamat, A., Alias, R., Hikmi, S., Puteh, M., & Tapsir, S. (2017). *Higher Education 4. 0 (2017). Current Status and Readiness in Meeting the Fourth Industrial Revolution*. Ministry of Higher Education Malaysia, August, pp. 23–24

Skilton, M., & Hovsepian, F. (2018). *The Fourth Industrial Revolution: Responding to the Impact of Artificial Intelligence on Business.* Basingstoke: Palgrave Macmillan

Stearns, P.N. (2018). *The Industrial Revolution in World History.* (4th ed.). New York: Routledge

Sung, Y., Chang, K., & Liu, C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computer Education* 94: 252–275

Taylor-Sakyi, K. (2016). Big Data: Understanding Big Data. Available at: https://arxiv.org/ftp/arxiv/papers/1601/1601.04602.pdf.

Tymon, A. (2013). The student perspective on employability. *Studies in Higher Education*, 38: 841–856

Vartan, G. (2014) American Higher Education: An Obligation to the Future. Carnegie Reporter, https://higheredreporter.carnegie.org/ introduction

Vries, P. (2008). Encyclopedia *of the Modern World.* Vol. 4. Oxford: Oxford University Press.

World Economic Forum. (2016). The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution, Geneva: World Economic Forum. http:// www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

World Economic Forum (2018). The Future of Jobs Report 2018; Insight Report; World Economic Forum: Geneva, Switzerland, pdf online:http://image-src.bcg.com/Images/BCG-Most-Innovative-Companies-Jan-2018_tcm38-179354

Xing, B., & Marwala, T. (2007). Implications of the Fourth Industrial Age for Higher Education. The_Thinker__Issue_73__Third_Quarter_2017. Available online: https://ssrn.com/abstract=3225331

Yusuf, B., Walters, M., & Sailin, S. (2020). Restructuring Educational Institutions for Growth in the Fourth Industrial Revolution (the Fourth Industrial Revolution): A Systematic Review. *iJET* 15(3): 93-10

Student Experiences of Emergency Remote Learning: Implications for Migration to Fourth Industrial Revolution by Higher Education Institutions in South Africa

T. Simelane*, E. Ojo**, & A. J. Onwuegbuzie***

*Human Sciences Research Council (HSRC)

**School of Education, University of the Witwatersrand

***Faculty of Education, University of Cambridge & Department of Educational Leadership and Management, University of Johannesburg

Corresponding author: Tsimelane@hsrc.ac.za

Abstract

This paper presents an analysis of university students' experiences of emergency remote learning, which took place in South Africa during the Covid-19 lockdown. Qualitative data from 4433 students were analysed using thematic analysis. Results reflected five broad categories of experiences, which are electricity and internet (infrastructure), home (environment), personal, health and other heterogeneous experiences. Electricity and internet represent infrastructure needed to participate in remote teaching and learning. The environment, which is home was found not to be conducive for students to participate effectively in remote teaching and learning. Additionally, students experienced increases in health conditions such as depression, anxiety and stress. Personal experiences, that include lack of motivation, laziness, time management and self-discipline deterred students from committing themselves to study remotely. These experiences provide insight into what university students may expect in the new era of blended remote learning in higher education institutions. The findings reveal a need for South African universities and the Department of Higher Education and Training (DHET) to create standards, policies and guidelines for moderating online content delivery in a blended remote teaching and learning environment.

Keywords: University, student experience, emergency remote learning, higher education, qualitative data

Introduction

Higher education is a significant contributor to national and global development goals (Heleta & Bagus, 2021; Chankseliani *et al*., 2021). Over the past decades, low-income and developing countries have seen a significant growth in the demand for higher education (Heleta & Bagus, 2021). In South Africa, rising demand has emphasised the importance of higher education in the National Development Plan (Cloete, 2014). The position for higher education in human development has rapidly changed, especially as the global economy has become more knowledge-based (Hazelkorn, 2013; Marginson, 2010; Välimaa & Hoffman, 2008). Technology has since taken a centre stage in the changing role of higher education as sophisticated web-based learning systems are continuously developed and used for engagement between students and lecturers, and to facilitate teaching and learning linkages

across global universities (Hong & Songan, 2011; Coates *et al*., 2005; De Freitas *et al*., 2015). As De Freitas *et al*. (2015) asserted, open online courses have made learning a significant aspect of life-long human development, how human beings learn, for how long, where and when they can engage with each other and educators. Through the use of web-based technologies, higher education institutions have integrated home and university as an environment where teaching and learning can take place seamlessly (Ellis & Goodyear, 2016). The effectiveness of this combination has not yet been fully understood, both in terms of the efficacy of computers replacing human beings and how students interact with computers. This is despite the fact that remote education has existed for decades and has been included into the South African university system. The notable example is the University of South Africa, which has been remotely interacting with students for many years.

The 2020 academic year triggered an unprecedented change to the operations of higher education institutions that were relying on traditional face-to-face, contact engagement with students. A global pandemic which started in Wuhan, China, in December 2019, caught the global academic institutions off guard. This led to shutdowns, as the behaviour, mode, and rate of the incidence of SARS-CoV-2 infection, commonly referred to as coronavirus or Covid-19, was unknown. Schooling and other business operations were closed and thus severely disrupted (UNESCO, 2020). Students were shut out of academic institutions, including universities, prompting a rapid shift to web-based teaching and learning in order for many universities to survive the academic year.

With little prediction that Covid-19 will come and have such a disruptive effect on academic programmes, universities across the world shifted teaching and learning online, integrating various web-based techniques and technologies in their systems. These included South African universities many of which speedily implemented what is now referred to as 'emergency remote teaching and learning' (Czerniewicz *et al*., 2020). The impact of Covid-19 on higher education is a novel research gap that requires ongoing investigation to advance global understanding. Such knowledge will aid higher education institutions to adapt to a 'new normal' whereby teaching and learning take place remotely via computers and web-based media of interaction, rather than in the conventional campus-based classrooms.

In exploring this, the paper draws on the qualitative data collected from students at a South African University. The data was collected through an online survey conducted at the height of the Covid-19 lockdown in South Africa in 2020. The purpose was to determine how students coped with remote learning through web-based teaching and learning during the lockdown. This indirectly tested a hypothesis that student-lecturer interaction through computers has some unintended effects. Thus, this paper presents students' experiences and perceptions of remote learning during periods of emergency. The analysis and interpretation of data provide implications this form of interaction might have on South African higher education.

Statement of the problem

The emphasis of this paper is on students' experiences interacting with lecturers via computers and web-based technologies in the context of emergency remote learning. While technology has become the preferred platform for teaching and learning in higher education institutions, little is known about students' reactions to and experiences with these arrangements (Czerniewicz *et al*., isbn).

As argued by Hodges *et al.* (2020) computer-based learning, which is synonymously referred to as

online learning, offers various experiences that are meaningfully different from courses offered in the classroom. As such, there are various opinions on modalities for migration to remote teaching and learning in the higher education institutions. This paper examines some of these modalities. It pays special attention to how university students at a research-intensive university in South Africa have experienced remote learning and online interaction with lecturers at the peak of the Covid-19 lockdown. As this adjustment is emerging in many higher education institutions in South Africa and globally, the paper presents perspectives and insights from South Africa based on qualitative data of written responses to an online questionnaire.

Aim and objectives

The primary aim of the paper is the assessment of student's experiences of remote learning and how they experience the interaction with lecturers through computers as a medium of instruction during the emergency situation created by Covid-19. It sought to provide an understanding of student's experiences and challenges they encountered. It further sought to identify opportunities this present for future design, planning and organisation of learning through computer-based medium in higher education institutions in South Africa.

The overarching question addressed was, 'what is the learning experience of university students in an emergency remote context at a South African university?' On the basis of this overarching question, two additional research questions were also investigated. These are:

- What was the experience of university students interacting with lecturers at a South African university in a virtual environment as a result of the disruption caused by the Covid-19 lockdown?
- What challenges did these university students encounter in the remote teaching and learning context, using technology as a medium of interaction at a South African university?

The broader objective was to contribute to the body of knowledge that is being developed. This insight illustrates the potential opportunities of moving to online and other web-based methods for teaching and learning in South African higher education institutions.

Literature review

Prior to the Covid-19 pandemic, technological advancements in higher education institutions were under serious consideration. However, the pandemic's disruption has expedited this process. It has served as a catalyst for full migration to computer-based interactions between students and lecturers (Burki, 2020). This directly impacted teaching and learning (Pokhrel & Chhetri, 2021; Carrillo & Flores, 2020; Bao, 2020). The consequential effects noted in some literature has been the mental instability of students and lecturers (Sahu, 2020; Onwuegbuzie et al., 2020). This represents one of the well-researched responses to student-lecturer interaction through remote platforms such as computers. As a result, the question of whether computers can fully replace traditional learning environment on university campuses which include physical contact with human beings, has been successfully explored by various scholars (Ebben & Murphy, 2014; Pérez-Sanagustín *et al*., 2012; Lin et al., 2021). There is a growing consensus that higher education institutions need to cautiously adapt to the emerging academic trend where medium of engagement between students and lecturers is through computers. This suggests that the Fourth Industrial Revolution is playing a role in changing higher education in South Africa (Xing, 2019).

While literature on the adaptation of higher education to computer based teaching and learning in South Africa is still evolving, authors like Ojo and Onwuegbuzie (2020) and Mhlanga and Moloi (2020) have interrogated the link between digital transformation in South Africa due to Covid-19 pandemic and the Fourth Industrial Revolution. The authors characterised various experiences of migration to remote learning, indicating that there are different strategies adopted as indicators of adaptation to remote learning but not necessarily as tools for migration to the Fourth Industrial Revolution. Higher education in the era of the Fourth Industrial Revolution goes beyond simple adaptation but entails the development of policies, standards, procedures and strategies for nurturing knowledge, skills and capabilities with computers being the medium of interaction between a learner and the instructor.

For higher education institutions, the major issue is about transforming the key elements of university operations including teaching and learning, research and innovation, service and infrastructure (Xing, 2019) and how these can be adapted to computer-based platforms of teaching and learning. Just as Xing (2019) pointed out, what has happened during the Covid-19 pandemic is not the ideal online learning that brings about the desired transformation needed to take place in the higher education institutions. It is about a shift to cater for the disruption caused by universities adapting and innovating in an uncertain future (Ojo & Lorenzini, 2021).

The following section reviews the research on students' perceptions of computer-based teaching and learning, which is sometimes referred to as online learning. Insights from the literature examined present the link between student-computer interaction and some of the arguments on online learning in an emergency learning situation.

Covid-19 and students' experience of remote learning

Literature on university students' experiences of online teaching and learning presents a multiplicity of descriptions (Anthonysamy *et al.*, 2020; Prifti, 2020; Onwuegbuzie *et al.*, 2020). These point to the existence of varied institutional student perceptions (Bowyer & Chambers, 2017), which offer insights for higher education institutions to structure their adaptation strategies for teaching, learning, and research using computer technologies (Dang *et al.*, 2016,; Ma'arop & Embi, 2016; Smith and& Hill, 2019; Medina, 2018).

The magnification of the divide between traditional and online instruction by the Covid-19 pandemic has been given special focus by most literature (Smith & Hill, 2019; Medina, 2018; Van Laer & Elen, 2017; Young, 2002). Although the Covid-19 pandemic and the resultant lockdown can be considered to be the push for higher education institutions to experiment with various models of interactions with students (Clark *et al.*, 2020), it can be argued that remote teaching and learning partially succeeded to save the 2020 academic year of many universities. The evidence is presented not just by the number of students who managed to continue stay on and complete their courses, but also how universities worldwide manage the transition to online or digital platforms.

Theoretical perspectives of student-computer interaction

According to Hillen and Landis (2014), the situationist perspective on learning highlights the idea that the learned knowledge has to be used in real life. As implied by the situationist perspective's proponents, authentic activities such as learning via experience and participation are the fundamental practices of higher education institutions. This extends beyond the acquisition of knowledge via online platforms

powered by computers. Such authentic activities are critical for the development of knowledge in an employable form in the future, through the application of gained skills in the workplace and in students' lives (Hillen & Landis, 2014). This presents an intriguing question about the evolution of knowledge domains at higher education institutions as they transition to computer-based teaching and learning. Will these assist students to develop to balanced (in terms of knowledge and social engagement) and skilled (in terms of practical know how) beings? Collectively, this requires assessment of whether the knowledge acquired through remote teaching and learning will be able to prepare students for real life.

Selwyn and Jandrić (2020) suggested that global perspectives on technology and education are necessary. Like these authors, Hillen and Landis (2014) indicated that this need to take into consideration three long standing theories of learning that has been widely researched in the past. These are behaviourism, cognitivism, and constructivism theories. Behaviourism is a theory of learning which states that all behaviours are learned through interaction with the environment through a process called conditioning. Thus, behaviour is simply a response to environmental stimuli (Schunk, 2012). Cognitivism on the other hand is a learning theory which stipulates that mental processes mediate learning and learning entails the construction or reshaping of mental schemata (Schunk, 2012). It is a learning theory that focuses on the processes involved in learning rather than on the observed behaviour. Constructivism is the theory that says learners construct knowledge rather than just passively take in information (Schunk, 2012).

These ideas emphasise four essential aspects of teaching and learning. To begin, there is the perspective that acquired information must be used in actual life. Second, there is the critical role of environment in moulding a student's behaviour. Thirdly, the notion that mental processes are necessary for learning and that learning requires the creation or reshaping of mental schemata. Fourthly, some believe that rather than passively absorbing information, learners construct their knowledge. These factors raise the question of whether developing platforms for teaching and learning will increase existing understanding of the frameworks and processes of knowledge acquisition, its application in real life, and the cognitive growth of students to become responsible citizens.

Notably, the academic disruptions caused by Covid-19 compelled South African higher education institutions to substantially integrate computer-based teaching and learning into their systems. Some have heralded the Covid-19 disruptions as the ideal time for higher education institutions to fully adopt the Fourth Industrial Revolution. Regrettably, this demand is made without adequate regard for students' experiences and views.

Conceptual framework for understanding student experiences of remote teaching and learning

As previously stated, the emergency remote teaching and learning adopted by higher education institutions during Covid-19 pandemic had a positive impetus on the 2020 academic year. However, student's experiences varied across many universities in different countries. While most institutions already had learning management systems in place to serve as an online platform for teaching and learning exchanges, the lockdown isolated students in their homes, which might not be conducive to learning. South Africa due to its endemic inequality in its education system (Leibowitz & Bozalek, 2014) present a diversity of learning experiences for university students. Jaffer *et al*. (2007) had argued

for the use of information and communication technologies as a 'strategy for addressing teaching and learning challenges' in South African higher education institutions.

Four areas of relevance that exhibit a stark disparity depending on the student's economic background and position are worth considering in this paper. These are environment (home), infrastructure (computers, internet connectivity and electricity), interactions (represented by student-lecturer relationship, student-student relationship, and student-technology interaction) and self-directed learning (discipline, personal commitment, and motivation). The relationship between each of these is explored in this paper. Teaching and learning within the university are an integrated process and a symbiotic relationship between the faculty and students. The student-teacher relationship is part of the learning continuum and cannot be assumed away either teaching is happening synchronously or non-synchronously (Crone *et al*., 2021).

University teaching and learning environment in a traditional, classroom context brings together students and lecturers in close proximity to interact. The 'space' on campus is uniquely designed to make teaching and learning possible because of the infrastructure the environment provides. While the online learning management system supplements classroom instruction, social interactions on campus foster possibilities that extend beyond the individual student's home environment. The social interaction in the classroom is a critical element of what is missing in an emergency remote teaching and learning context. Instead, the lockdown focused university students into self-isolation solely relying on their online connections with peers, lecturers, and administrative support. Based on this perspective, it is proposed that student-computer interaction happens at the intersection of interactions at three levels: student-lecturer, student-student, and student-technology. This student-centred approach is critical for understanding the experiences of students.

Graham *et al*. (2018) acknowledged the importance of on-campus residence for university students as a best environment to acquire knowledge and develop skills. The authors suggested that on-campus residence provide a distinctive environment for engagement and interaction among university students as peers. The Covid-19 epidemic precipitated a major shift toward home as an alternate learning environment for university students without thoroughly examining whether students' homes are truly suited for teaching and learning. Nevertheless, it is acknowledged that any environment or home situation is pivotal to student's learning. All the four contexts earlier presented (environment, infrastructure, interactions and self-directed learning*)* constitute students' learning experiences that is explored in this paper.

University students' self-directed learning has been argued to be critical to the success of students' acquisition of knowledge and skills development (Tekkol & Demirel, 2018). Through self-directed learning, students take responsibility for transforming themselves into responsible adults (Merriam & Baumgartner, 2020). Students, through self-directed learning take the responsibility to master discipline and ultimately shift from an external source (for example, a teacher) of influence to individuals that take full responsibility for their journey to adulthood (Tekkol & Demirel, 2018). This notion of self-directed learning is considered as central in understanding student's experiences of remote learning (Figure 1).

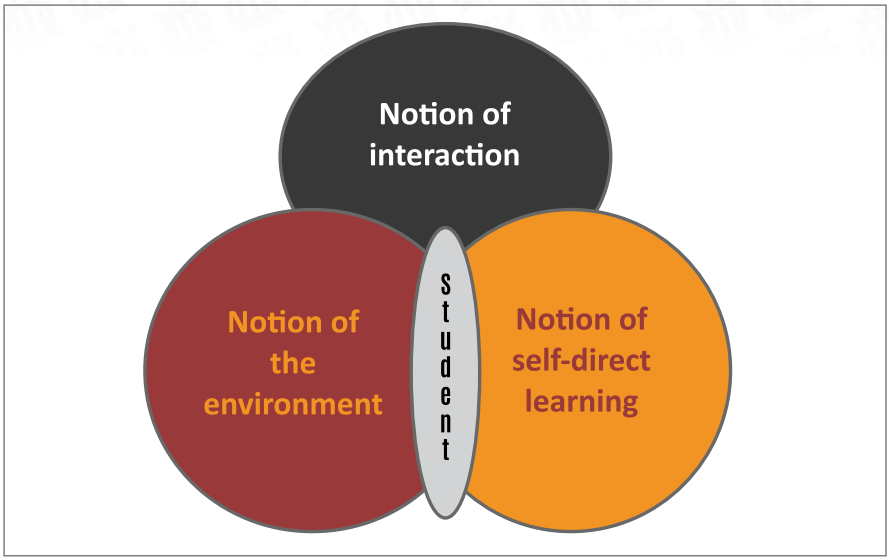

Figure 1: Authors' Illustration of 'Interaction-Environment-Self-directed Learning' (IES) Conceptual framework for understanding student's remote learning experience.

In the illustration above (Figure 1), university students constitute the core of the relationship of the three notions with a strong bond amongst these three notions. This conceptual framework will be drawn upon as a lens on the results presented in the discussion section.

Methodology

The paper adopted a qualitative empirical approach. After ethics clearance approval was granted by the South African University, data was collected at the institution through an online questionnaire which included questions about the students' demographics, as well as Likert scale questions on their experiences. For the purpose of this paper, the open-ended questions were used. Students were asked to share their experiences during the emergency remote learning in the open-ended questions. The responses were processed and rearranged for analysis through Microsoft Excel. The data was quantified by examining the frequency of the meanings. A thematic analysis was performed with results presented descriptively.

Students' experiences of emergency remote learning

A total of 4433 responses from the open-ended questions were obtained. Eighty-eight percent of respondents were full-time students who were mostly female (62%) and predominantly South Africans (96%). These were mostly between the ages of 18 and 24 years (77%). They were mostly undergraduates (74%) in the faculty of Humanities (33%) (Figure 2).

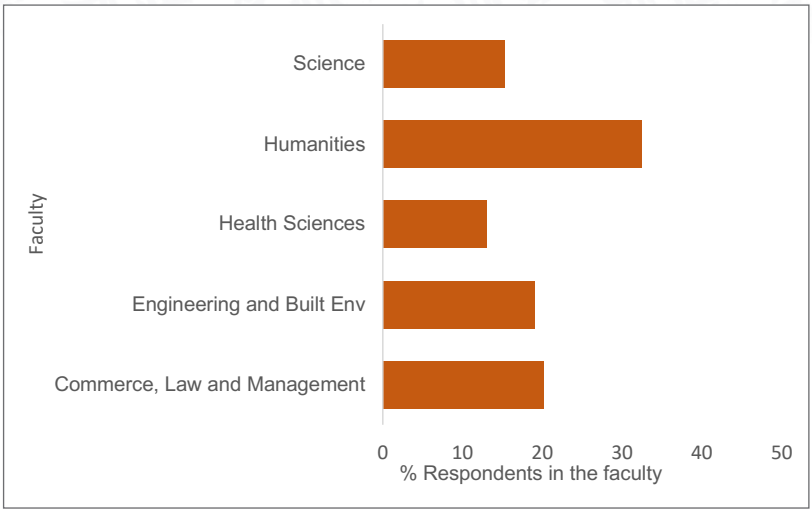

Figure 2: Faculty representations

The two dominant devices used at home for participation in remote learning were smartphones (83%) and laptops (75%). Tablets and desktop computers together accounted for 17% of the devices used. The mobile communication service provider was mostly Vodacom (41%) followed by MTN (25%) and Telkom (19%). See Figure 3.

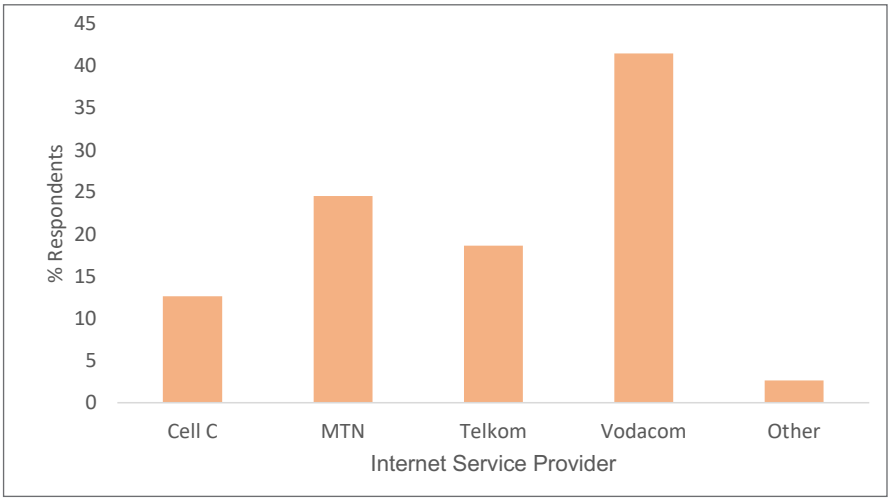

Figure 3: Internet services providers

Five broad categories of concerns from responses reflect that student were struggling with the reliability of electricity, owning a device like computer, internet stability, access to data and its cost.

These concerns were classified as infrastructure required for remote learning. In addition, distractions, noise, competing responsibilities and space availability were mentioned and classified as features reflecting home context and the environment students were experiencing at home (Figure 3).

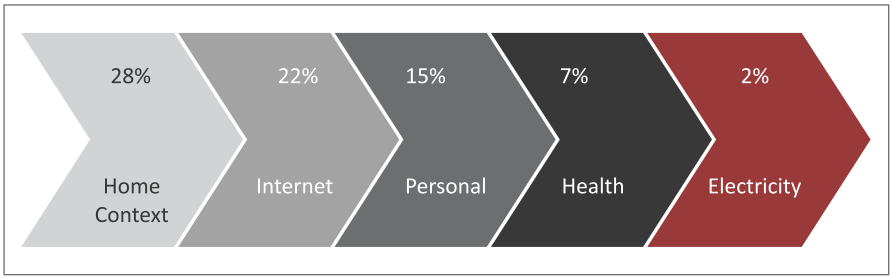

Figure 4: Five broad categories of concern raised by students

Anxiety, depression, stress, and conditions like ADHD reflected health experiences of students as they were working from home. At personal level students felt they were lacking concentration, motivation and self-discipline. These were classified as personal factors. They were unable to manage time and could not cope with workload. Generally, they were missing the university environment and interaction with peers. Experiences like these were classified as heterogenous experiences.

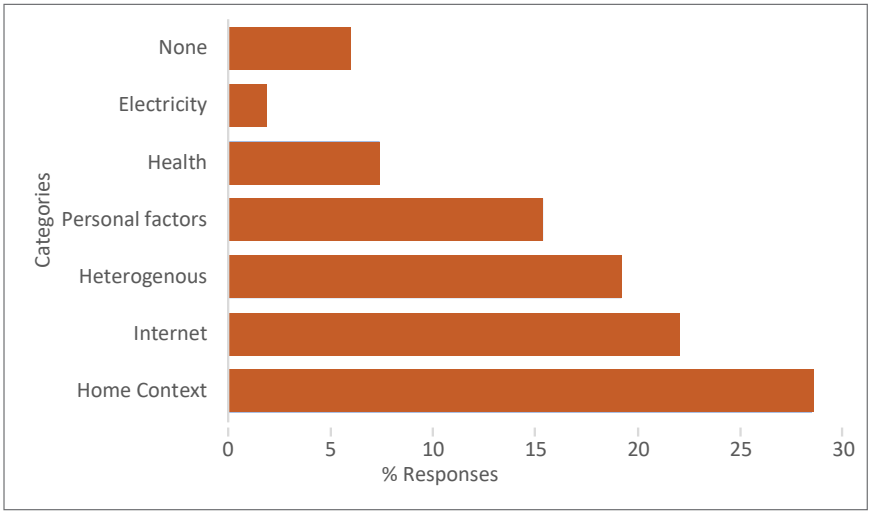

Figure 5: Categories of responses received

The detailed analysis of each of the categories reflected that each category is diverse and can be further broken down into subcategories.

Among these two recognisable concerns that represented infrastructure are electricity and internet. Respondents struggled with the reliability of network connection, which was unstable. Some could not afford data, which they said was expensive. Unreliable electricity supply, known as load shedding

in South Africa, occurred during the Covid-19 lockdown, contributed to the volatility of internet connections. See Table 1.

Table 1: Concerns raised under infrastructure

Concern	Number of responses	%
Network	173	17%
Data	434	43%
Internet connectivity	218	22%
Access to internet	124	12%
Owning a computer/device	63	6%

The environment, represented by the home, was mentioned as unsuitable for learning. Some of the reasons given were competing duties at home, noise in the house and the neighbourhood, conflict at home, a limited space, a lack of equipment such as a desk and chair, interruptions, financial restrictions, and a lack of privacy. See Table 2.

Table 2: Main elements of concern under home context

Concern	Number of responses	%
Multitasking when at home	60	6%
Noise: Home and neighbourhood	64	6%
Family	68	7%
Space	126	12%
Lack of furniture and other amenities	6	1%
Disruptions and disturbances	109	11%
Home not suitable to study	600	58%

Students exhibited increased stress, anxiety, depression, headache and attention deficit hyperactivity disorder as a result of working in an unfavourable setting. This was exacerbated by students' lack of requisite skills such as time management, self-discipline, procrastination, necessary for them to adjust to the home learning environment. See Table 3.

Table 3: Main elements of concern under health

Concern	Number of responses	%
Stress	35	14%
Anxiety	105	43%
Depression	28	11%
Headache	3	1%
ADHD	11	4%
Mental Health	64	26%

Students struggled with work overload, laziness, procrastination, and time management on a personal level, all of which were classed as personal issues. Most responders struggled with time management. See Table 4.

Table 4: Main elements of concern under health

Concern	Number of responses	%
Time management	236	39%
Discipline	107	18%
Procrastination	48	8%
Motivation	95	16%
Laziness	9	1%
Inability to concentrate	42	7%
Workload	67	11%

In addition to experiences that were clearly categorised, a total of 871 individual experiences were recorded. The frequencies for each of these concerns were less than 10%. Most appeared once with concerns like loss of interaction with peers (0.002%), loss of interaction with lecturers (0.01%), unable to use library (0.003%), loss of helpful consultation with lecturers (0.002%) and loss of income (0.001%) being prominent concerns recorded.

Discussion

The concerns raised by students confirm that under emergency remote learning, students have experienced five broad categories of challenges. These are electricity and internet (infrastructure), home (environment), personal, health and other heterogeneous experiences. Although these are the difficulties the students encountered, they are also critical criteria for them to engage successfully in emergency remote learning. When these five categories are superimposed on the conceptual framework, the notion of interaction becomes associated with personal and health challenges, the *notion of self-directed learning* becomes associated with other heterogeneous experiences, and the *notion of environment* becomes associated with the internet and home. These findings corroborate earlier study on students' experiences with remote learning during the current worldwide epidemic (Mhlanga & Moloi, 2020; Rahiem, 2020; Rotas & Cahapay, 2020; Rousseau *et al*., 2020; Onwuegbuzie *et al*., 2020; Ojo & Onwuegbuzie, 2020).

A significant result on student mental health validates previously established health issues experienced by students of higher education institutions (Schreiber, 2018; Wörfel *et al*., 2016; Hamad *et al*., 2008). Specifically at another South African research-intensive university, Onwuegbuzie *et al*. (2020) confirmed that students experienced mental health challenges like stress, anxiety and depression. Their findings revealed a gender dimension to mental health. According to the authors, female students were 1.83 times as likely than male students to report mental health issues. Suicides have been recorded at the University of the Witwatersrand, Stellenbosch University, and other South African higher education institutions. These occurrences, together with our findings that corroborate what has been published in the literature, attest to students' health difficulties. This appears to have reached an all-time high during the emergency remote learning as a result of the Covid-19 pandemic.

Given that students, at the time of writing this paper students were not on campus, universities need to adjust their policies in order to provide students with the assistance they need when they are not on campus and are learning remotely. According to Schreiber (2018), such assistance should focus on eco-systemic interventions, working toward a caring and engaging institutional framework, focus on promoting help-seeking behaviours, and focusing on at-risk populations. Other health challenges were implied from some of the challenges they included in their responses. Although the university students' responses to the open-ended questions did not specify their health challenges are apart from mental health issues, they directly made mention of, it is clear that transitioning to remote learning had not been an easy process for these students. In general, the Department of Higher Education and Training (DHET) needs to collaborate with Higher Health and South African universities to develop guidelines for assisting students who face health challenges, including reaching out to them in remote locations to assist them in continuing their education during this trying time.

Students' personal challenges at universities, as presented in this paper as one of the categories of challenges that student faced during emergency remote teaching and learning, had caught the attention of many researchers (Doygun & Gulec, 2012; Marsh& O'Mara, 2008; Ryan *et al*., 2021). For example, Doygun and Gulec (2012) listed food and housing, habituation and orientation, unemployment and future anxiety, and worries about the quality of education as typical personal problems faced by students enrolled in higher education institutions. Along with the mental health condition described as a concern in this paper, failure to manage time, a lack of discipline, and motivation are also mentioned as personal obstacles. While they may be unique to emergency remote learning, they demonstrate

students' inability to manage themselves and work independently in the absence of lecturers. What they have expressed as challenges are self-directed learning skills (Tekkol & Demirel, 2018, Nyadanu *et al*., 2015) needed to cope with the workload of university demands. Universities always provide on-site support in the form of consultations with lecturers, tutorials, and group discussion to aid students in coping. Remote learning does not incorporate these additional learning and engagement activities, leaving students feeling alone and excluded. This may be why students who participate in remote learning report greater personal challenges including anxiety and depression, and thus feel unmotivated to continue with their studies. To address this, programmes and interventions that prepare students to work independently and successfully engage with lecturers via remote learning must be established. Again, this underscores the need of institutions going an extra mile in orientating students, particularly those at the undergraduate level.

As it has been illuminated in this study, the home is not an ideal environment to learn as a university student. It offers a different experience to the facilities available on campus. Students appear to be more comfortable at home, and as a result, do not devote to their academic work. Due to competing family obligations, several students find themselves with little time for academic study. Some lack basic infrastructure, such as a study area equipped with a table and seats. This exemplifies the reality that many students from previously disadvantaged economic backgrounds confront when it comes to remote teaching and learning. A balanced curriculum should be created that allows students to spend time at home while simultaneously visiting university campuses.

This paper has added students' voices to the evolving knowledge on the impact of the global pandemic on higher education, specifically in South Africa. The depth of the challenges presented in this article cannot be handled by just the universities in South Africa. University authorities and moderating institutions like the Council for Higher Education (CHE) should work together to create practical interventions beyond just standards, policies and procedures to build effective blended learning experience in South African higher education. This will be creative and transformative for South African higher education, since it will enhance the critical aspects (teaching and learning, research and innovation, service, and infrastructure) in the Fourth Industrial Revolution (the Fourth Industrial Revolution), as Xing (2019) argued.

Concluding remarks

This paper discussed the challenges that university students have while adapting to emergency remote teaching and learning because of the continuing global epidemic. It presented the implications for South African higher education in the era of the Fourth Industrial Revolution through the results and discussion sections, drawing on the literature and conceptual framework earlier developed by the authors. The paper has provided crucial insight into university students' voices and argued that this is critical for determining the future of higher education in South Africa beyond pandemics. While computers cannot entirely replace human interaction with students and lecturers in today's blended learning environment, building back a better higher education system would require multiple stakeholder engagements including at the institutional and national levels.

References

Anthonysamy, L., Koo, A.C.; & Hew, S.H. (2020). Self-regulated learning strategies and non-academic outcomes in higher education blended learning environments: A one decade review. *Education and Information Technologies*,: 1-28

Bao, W. (2020). COVID-19 and online teaching in higher education: A case study of Peking University. *Human Behavior and Emerging Technologies,* 2**:** 113-115

Bowyer, J., & Chambers, L. (2017). Evaluating blended learning: Bringing the elements together. *Research Matters: A Cambridge Assessment Publication,* 23**:** 17-26

Burki, T. K. (2020). COVID-19: consequences for higher education. *The Lancet Oncology,* 21**:** 758

Carrillo, C., & Flores, M. A. (2020). COVID-19 and teacher education: a literature review of online teaching and learning practices. *European Journal of Teacher Education,* 43**:** 466-487

Chankseliani, M., Qoraboyev, I., & Gimranova, D. (2021). Higher education contributing to local, national, and global development: new empirical and conceptual insights. *Higher Education,* 81**:** 09-127

Clark, A., Jit, M., Warren-Gash, C., Guthrie, B., Wang, H. H., Mercer, S. W., Sanderson, C., Mckee, M., Troeger, C., & Ong, K. L. (2020). Global, regional, and national estimates of the population at increased risk of severe COVID-19 due to underlying health conditions in 2020: a modelling study. *The Lancet Global Health,* 8**,** e1003-e1017

Cloete, N. (2014). The South African higher education system: Performance and policy. *Studies in Higher Education,* 39**:** 1355-1368

Coates, H., James, R., & Baldwin, G. (2005). A critical examination of the effects of learning management systems on university teaching and learning. *Tertiary education and management,* 11**:** 19-36

Crone, C. L., Rigoli, L. M., Patil, G., Pini, S., Sutton, J., Kallen, R. W., & Richardson, M. J.(2021). Synchronous vs. non-synchronous imitation: Using dance to explore interpersonal coordination during observational learning. *Human Movement Science,* 76**:** 102776

Czerniewicz, L., Agherdien, N., Badenhorst, J., Belluigi, D., Chambers, T., Chili, M., De Villiers, M., Felix, A., Gachago, D., & Gokhale, C. (2020). A Wake-Up Call: Equity, Inequality and COVID-19 Emergency Remote Teaching and Learning. *Postdigital Science and Education,* 2**:** 946-967

Dang, Y. M., Zhang, Y. G., Ravindran, S., & Osmonbekov, T. (2016). Examining student satisfaction and gender differences in technology-supported, blended learning. *Journal of Information Systems Education,* 27**:** 119

De Freitas, S. I., Morgan, J., & Gibson, D. (2015). Will MOOCs transform learning and teaching in higher education? Engagement and course retention in online learning provision. *British journal of educational technology,* 46**:** 455-471

Doygun, O., & Gulec, S. (2012). The problems faced by university students and proposals for solution. *Procedia-Social and Behavioral Sciences,* 47**:** 1115-1123

Ebben, M., & Murphy, J. S. (2014). Unpacking MOOC scholarly discourse: A review of nascent MOOC scholarship. *Learning, media and technology,* 39**:** 328-345

Ellis, R. A. & Goodyear, P. (2016). Models of learning space: integrating research on space, place and learning in higher education. *Review of Education,* 4**:**149-191

Graham, P. A., Hurtado, S. S. & Gonyea, R. M. (2018). The benefits of living on campus: Do residence halls provide distinctive environments of engagement? *Journal of Student Affairs Research and Practice,* 55**:** 255-269

Hamad, R., Fernald, L., Karlan, D., & Zinman, J. (2008). Social and economic correlates of depressive symptoms and perceived stress in South African adults. *Journal of Epidemiology & Community Health,* 62**:** 538-544

Hazelkorn, E. (2013). Higher Education's Future: A new global order?. *Resilient Universities, Confronting Changes in a Challenging World***:** 53-90

Heleta, S., & Bagus, T. (2021). Sustainable development goals and higher education: leaving many behind. *Higher Education,* 81**:** 163-177

Hillen, S. A., & Landis, M. (2014). Two perspectives on e-learning design: A synopsis of a US and a European analysis. *The International Review of Research in Open and Distributed Learning,* 15**:** 199-225

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. *Educause review,* 27**:** 1-12

Hong, K.S., & Songan, P. (2011). ICT in the changing landscape of higher education in Southeast Asia. *Australasian Journal of Educational Technology,* 27

Jaffer, S., Ng'ambi, D., & Czerniewicz, L. (2007). The role of ICTs in higher education in South Africa: One strategy for addressing teaching and learning challenges. *International journal of Education and Development using ICT,* 3**:** 131-142

Leibowitz, B., & Bozalek, V. (2014). Access to higher education in South Africa. *Widening Participation and Lifelong Learning,* 16**:** 91-109

Lin, C.-L., Jin, Y. Q., Zhao, Q., Yu, S.W., & Su, Y.S. (2021). Factors influence students' switching behavior to online learning under COVID-19 pandemic: A push–pull–mooring model perspective. *The Asia-Pacific Education Researcher***:**1-17

Ma'arop, A. H., & Embi, M. A. (2016). Implementation of blended learning in higher learning institutions: A review of the literature. *International Education Studies,* 9**:** 41-52

Marginson, S. (2010). Higher education in the global knowledge economy. *Procedia-Social and Behavioural Sciences,* 2**:** 6962-6980

Marsh, H. W., & O'Mara, A. (2008). Reciprocal effects between academic self-concept, self-esteem, achievement, and attainment over seven adolescent years: Unidimensional and multidimensional perspectives of self-concept. *Personality and Social Psychology Bulletin,* 34**:**542-552

Medina, L. C. 2018. Blended learning: Deficits and prospects in higher education. *Australasian Journal of Educational Technology,* 34**:** 42-56

Merriam, S. B. & Baumgartner, L. M. (2020). *Learning in adulthood: A comprehensive guide*, John Wiley & Sons

Mhlanga, D., & Moloi, T. (2020). COVID-19 and the Digital Transformation of Education: What Are We Learning on the Fourth Industrial Revolution in South Africa? *Education Sciences,* 10**:**180.

Nyadanu, S. D., Garglo, M. Y., Adampah, T., & Garglo, R. L. (2015). The impact of lecturer-student relationship on self-esteem and academic performance at higher education. *Journal of Social Science Studies,* 2**:** 264-281

Ojo, E., & Lorenzini, E. (2021). Global Higher Education Beyond Pandemics in the Future of Uncertainties. *Texto & Contexto-Enfermagem,* 30**:** 1-4.

Ojo, E. O., & Onwuegbuzie, A. J. (2020). University Life in an Era of Disruption of COVID-19: A Meta-Methods and Multi-Mixed Methods Research Study of Perceptions and Attitudes of South African Students. *International Journal of Multiple Research Approaches,* 12**:**20–55

Onwuegbuzie, A. J., Ojo, E. O., Burger, A., Crowley, T., Adams, S. P., & Bergsteedt, B. (2020). Challenges Experienced by Students at Stellenbosch University that Hinder their Ability Successfully to Learn Online during the COVID-19 era: A Demographic and Spatial Analysis. *International Journal of Multiple Research Approaches,* 12**:** 240-281

Pérez-Sanagustín, M., Ramirez-Gonzalez, G., Hernández-Leo, D., Muñoz-Organero, M., Santos, P., Blat, J., & Kloos, C. D. (2012). Discovering the campus together: a mobile and computer-based learning experience. *Journal of Network and Computer Applications,* 35**:** 176-188

Pokhrel, S., & Chhetri, R. (2021). A Literature Review on Impact of COVID-19 Pandemic on Teaching and Learning. *Higher Education for the Future***,** 2347631120983481.

Prifti, R. (2020). Self–efficacy and student satisfaction in the context of blended learning courses. *Open Learning: The Journal of Open, Distance and e-Learning***,** 1-15

Rahiem, M. D. (2020). The emergency remote learning experience of university students in indonesia amidst the COVID-19 crisis. *International Journal of Learning, Teaching and Educational Research,* 19**:** 1-26

Rotas, E. E., & Cahapay, M. B. (2020). Difficulties in Remote Learning: Voices of Philippine University Students in the Wake of COVID-19 Crisis. *Asian Journal of Distance Education,* 15**,** 147-158

Rousseau, K.-L., Thompson, S., Pileggi, L.-A., Henry, M., & Thomas, K. G. (2020). Trends in the prevalence and severity of depressive symptoms among undergraduate students at a South African University, 2016–2019. *South African Journal of Psychology***,** 0081246320977759

Ryan, T., Baik, C., & Larcombe, W. (2021). How can universities better support the mental wellbeing of higher degree research students? A study of students' suggestions. *Higher Education Research & Development***,** :1-15

Sahu, P. (2020). Closure of universities due to coronavirus disease 2019 (COVID-19): impact on education and mental health of students and academic staff. *Cureus,*12

Schreiber, B. (2018). Mental health at universities: Universities are not in loco parentis–Students are active partners in mental health. *Journal of Student Affairs in Africa*, 6

Schunk, D. H. (2012). *Learning Theories: An Educational Perspective*, Pearson.

Selwyn, N., & Jandrić, P. (2020). Postdigital living in the age of Covid-19: Unsettling what we see as possible. *Postdigital Science and Education,* 2**:** 989-1005

Smith, K., & Hill, J. (2019). Defining the nature of blended learning through its depiction in current research. *Higher Education Research & Development,* 38**:** 383-397

Tekkol, İ. A., & Demirel, M. (2018). An investigation of self-directed learning skills of undergraduate students. *Frontiers in psychology,* 9**:** 2324

Unesco. (2020). 1.3 billion learners are still affected by school or university closures, as educational institutions start reopening around the world, says UNESCO. Available: https://en.unesco.org/news/13-billion-learners-are-still-affected-school-university-closures-educational-institutions.

Välimaa, J., & Hoffman, D. (2008). Knowledge society discourse and higher education. *Higher education,* 56**:** 265-285

Van Laer, S., & Elen, J. (2017). In search of attributes that support self-regulation in blended learning environments. *Education and Information Technologies,* 22**:** 1395-1454

Wörfel, F., Gusy, B., Lohmann, K., Töpritz, K., & Kleiber, D. (2016). Mental health problems among university students and the impact of structural conditions. *Journal of Public Health,* 24**:** 125-133

Xing, B. (2019). Towards a Magic Cube Framework in Understanding Higher Education 4.0 Imperative for the Fourth Industrial Revolution. *In:* KHOSROW-POUR, M. (ed.) *Handbook of Research on Challenges and Opportunities in Launching a Technology-Driven International University.* United States of America: IGI Global.

Young, G. (2002). 'Hybrid' Teaching Seeks to End the Drive Between Traditional and Online Instruction. *The Chronicle of Higher Education*.

Prospects and Challenges of IntegratingTechnology into Pedagogy in South African Higher Education Institutions in the Context of the Fourth Industrial Revolution

M. Sibanda, & F.N. Fon

Faculty of Science, Agriculture & Engineering,

University of Zululand

Corresponding author: SibandaM@unizulu.ac.za

Abstract

Higher education institutions widely embrace technology-enabled teaching and learning in the Fourth Industrial Revolution era. This paper reviews and critically discusses the prospects and opportunities of adopting these technologies, as well as the challenges they may come with in the context of the Fourth Industrial Revolution. The higher education sector is expected to drive and lead innovations in the Fourth Industrial Revolution, yet the implications of the Fourth Industrial Revolution in the higher education sector – a critical sector in any knowledge economy - remains less understood. In this context, understanding the opportunities and challenges of the Fourth Industrial Revolution concerning higher education in South Africa is essential. The research followed a desktop approach guided by the community of inquiry (CoI) theoretical framework. The results show that the integration of technology as a pedagogy in South African Higher education institutions in the context of the Fourth Industrial Revolution presents both some opportunities and challenges which are presented and discussed in the paper.

Keywords: Fourth Industrial Revolution, challenges, cyber education, higher education, information communication technology (ICT)

Introduction

The higher education sector is viewed as a means of 'social mobility, an engine for economic growth, and a defender of democracy' (Office of Educational Technology, 2017: 6). Globally the higher education sector has been under pressure for increased access, equity, and demand for continuous innovation (UNESCO-IESALC, 2020). The expectation is that innovation will create a range of opportunities for high-quality education suited for the marketplace and students' various needs (Henry *et al*., 2018).

Due to the changing global needs and increasing societal demands, in the 21st Century, higher education institutions are expected to evolve along with technological advancements to facilitate innovation from a curriculum point of view. Therefore, universities are compelled to shift their practices to meet these societal expectations (Attaran *et al*., 2017). Technology-enabled teaching and learning have emerged as a meaningful way for universities to optimise higher education needs in the 21st Century (Ng'ambi *et al*., 2016). There is now an increased demand to integrate emerging technologies in teaching and learning in a conducive environment where knowledge is conveniently accessible (Malik & Chaudhry, 2014).

The revolution in Information Communication Technology (ICT) and, most recently, the Fourth Industrial Revolution have seen an outburst of new technological tools in the higher education sector, especially during the Covid-19 pandemic period (Mhlanga & Moloi, 2020). The Fourth Industrial Revolution and automation economy are undoubtedly changing the way of life and work, including higher education (Gleason, 2018). In the 21st Century, information transfer is not the primary role of institutions of higher education. Instead, critical thinking coupled with innovation are paramount to solve complex global challenges. The higher education sector is expected to play a crucial role in society, including preparing the societal transitions necessary to adapt to a world of automation (the Fourth Industrial Revolution) economy.

The challenge is that the current higher education system, for example, was designed to meet the needs of previous industrial revolutions characterised by mass production powered by electricity (Penprase, 2018). Arguably the curricula of such a higher education system may not be appropriate to meet the automation (the Fourth Industrial Revolution) economy. Many challenges face society to varying degrees, and these include increasing population, unemployment, food insecurity, inequality, social justice issues, clean energy and climate change issues (Food and Agriculture Organisation (FAO), 2015) and most recently the global health (Covid-19 pandemic) (United Nations (U.N.), 2020). In the context of the Fourth Industrial Revolution and automation, students, educators, and researchers alike would work with technologies such as artificial intelligence (AI), machine learning, robotics, Internet of Things (IoT), big data analytics, quantum computing, among other technologies. In fact, the higher education sector should play a leading role concerning innovations that could significantly meet the global challenges and demands. Also, higher education institutions can influence policy concerning research and data-based evidence on the Fourth Industrial Revolution and related technologies.

Although the impact of the Fourth Industrial Revolution is unknown (Penprase, 2018), in literature, it is hypothesised that automation and the Fourth Industrial Revolution economy can benefit countries in tackling emerging global challenges. Despite the opportunities presented by automation and the Fourth Industrial Revolution, there is speculation regarding its challenges, mainly in Africa and developing countries. Most developing countries arguably still need to catch up on past industrial revolutions (Roodt & Koen, 2020). Also, less research has been conducted to understand the intricacies presented by automation and the Fourth Industrial Revolution, particularly for the higher education sector, which is a critical sector in any knowledge economy. Therefore, understanding the opportunities and challenges of the Fourth Industrial Revolution concerning higher education is essential to make a substantial shift towards knowledge and automation (the Fourth Industrial Revolution) based economies. So far there has been less appreciation of, and enthusiasm for the Fourth Industrial Revolution and technology-enabled teaching and learning in higher education in South Africa.

International trends of globalisation and internationalisation are also pushing the agenda of technology-driven teaching and learning in higher education. Technology pedagogy is hypothesised to have a potential effect on enhancing teaching and learning. Technology promises to combat some of the challenges unintentionally presented in the historically traditional classroom (Kuriloff, 2005). Integrating technology in the 21st Century could transform education to enhance student-centred learning relevant in the Fourth Industrial Revolution era (Howard *et al*., 2019). However, it is also important to note that technology can also present some challenges in the higher education sector, and these need to be taken into consideration. Ascough, cited in Cloete (2017), believes that effective

implementation of technology-driven pedagogy entails awareness of its opportunities and limitations in teaching and learning.

Objective and structure of the paper

This paper provides a critical analysis of the prospects and challenges of integrating technology into pedagogy in South African higher education institutions in the context of the Fourth Industrial Revolution. To achieve the paper's objective, first, a theoretical framework underpinning the study is provided, followed by an overview of the South African higher education. Subsequently, the notion of technology-driven pedagogy in the context of the Fourth Industrial Revolution is defined and discussed. This is followed by the presentation and discussion of results focussing on the prospects and opportunities. Lastly, the paper identifies and discusses challenges that the Fourth Industrial Revolution brings in its wake with respect to education systems.

Approach

This paper critically reviews the literature on the prospects and challenges of integrating technology into pedagogy in South African higher education institutions in the context of the Fourth Industrial Revolution. The research employed a desktop approach, and information was extracted from relevant literature sources. Government documents, reputable sources and peer-reviewed published material were considered. Unpublished and grey literature material were excluded. Literature sources were limited to those in English language. Articles were retrieved from search engines and indexes (databases): PubMed, Google Scholar, Science direct, and using the University of Zululand library catalogue search. The key terms used for searching included: challenges, the fourth industrial revolution (the Fourth Industrial Revolution), higher education, information communication technology, online learning, opportunities, South Africa, technology-enabled learning, cyberspace education, among other related words.

Theoretical framework

A theoretical framework is a structure that underpins or supports a theory central to particular research. Following Cleveland-Innes *et al*. (2019), this paper adopts the commonly used framework for technology-enabled learning – the community of inquiry (CoI) theoretical framework - to understand the opportunities and challenges of using technology-enabled teaching and learning in the context of online learning and the Fourth Industrial Revolution tools in higher education. Figure 1. summarises the elements of the CoI framework.

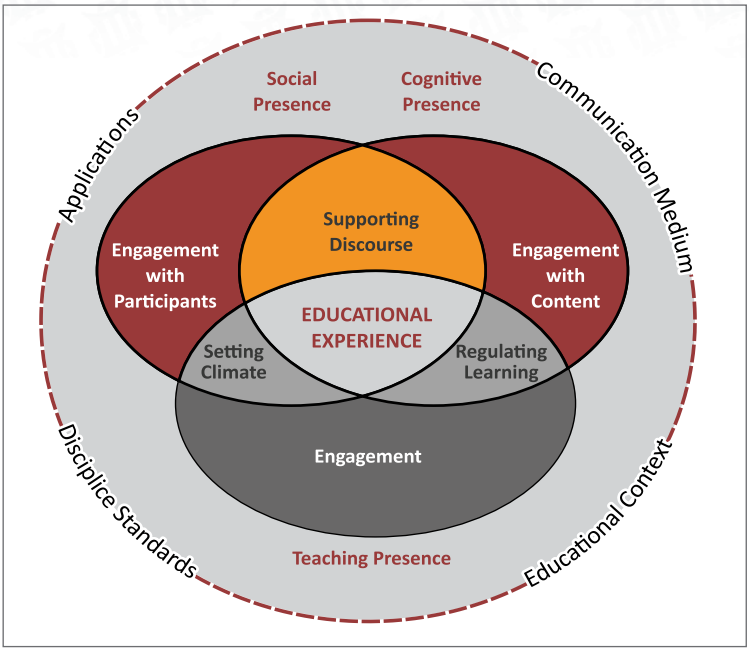

Figure 1: A summative description of the community of inquiry (CoI) theoretical framework

Source: *Garrison et al. (2000)*

The CoI framework depicts teaching and learning encompassing learning theory and practice and supports guided inquiry and deep, meaningful learning. According to Cleveland-Innes (2019), an online CoI theoretical framework consists of three types of support – instruction (offered two-fold through a virtual short video or text-based presentation/s of material), inspiration (facilitator providing communication, direction and encouragement that inspires learners) and information. The CoI model describes aspects encompassing three vital presences - social, cognitive, and teaching- that offer self-reflection, active cognitive processing, interaction, and peer-teaching. The social presence relates to the ability of individuals to identify with the community (course of study in this instance) and develop interpersonal relationships. Cognitive presence relates to the extent to which learners construct meanings with sustained reflections and through critical discourses. The teaching presence refers to the design, facilitation, and direction of social and cognitive processes meaningful to realize educationally worthwhile learning outcomes.

Higher Education in the South African context

Any university is a dynamic system that interacts with the broader community. In South Africa, the situation is no different from the rest of the world. The increasing demand for higher education in South Africa resonates with global trends and educational reforms. The ever-increasing unemployment rates, rise in population and globalisation forces all play roles in advancing demand for higher education. The recent hashtag #FeesMustFall movement and the decolonisation discourses in South Africa have also

placed considerable pressure on the higher education system. Coupled with the dwindling funding from the Department of Higher Education (DHET), Higher Education Institutions (Higher education institutions) seek other ways of achieving financial sustainability. Universities in South Africa have resorted to increasing student numbers to generate income. Massification has become a common trend in almost every university in South Africa (Tjønneland, 2017).

There have been concerns in South Africa about throughput rates that do not match the enrolment numbers. Other matters have been on underperforming students owing to passive learning. Some fears in South Africa have been raised by industry on the quality of graduate attributes. Nowadays, technology-enabled teaching and learning are becoming widely embraced by higher education institutions and practitioners. Technology-enabled teaching is becoming a norm in South Africa through, for example, blended learning and other online-based courses. There are some noted challenges of using technology in teaching and learning. However, incorporating a carefully designed technology into the teaching and learning processes has benefits for students.

The Fourth Industrial Revolution and technology-driven pedagogy in higher education

There are many ways in which people view technology. It is, therefore, essential to understand what technology is. At a very basic level, technology is primarily seen as keeping up with the times, particularly in a fast-changing world. There is no denying that technology has become part of everyday lives of human brigs globally, more so in this digital era. There is a tendency to view technology as devices (gadgets), say computers, and digital objects (Cloete, 2017). Particularly in the current era, at the realm of technology would be network infrastructure (receivers and transmitters for connectivity), AI and machine learning. However, Drees, cited in Cloete (2017), argues that technology is more than that.

Therefore, technology should be understood to be more than gadgets/devices, including attitude towards life (ability to analyse and develop practical ways to solve problems). Another dimension of technology mentioned by Hess (2002) is the idea of it as a medium for understanding. Drees (2002) also considers technology as culture (resembling identity, desires and values). The concept of technology as a culture incorporates social systems to provide specific skills and services. Such social networks would entail interactions between software, hardware infrastructure and the broader culture. In light of this, technology would be any resource (person or object) that communicates teaching and learning (Khoza, 2012).

Khoza's idea of technology in teaching and learning comprises mainly two categories – Technology in education (TIE) and Technology for Education (TOE). TIE depicts the hardware and software (machines, tools, and materials) used in teaching and learning, while TOE refers to resources that cannot be seen nor touched. The emphasis to understand technology is motivated by the idea that it is sophisticated and cannot be merely limited to objects (computers and other digital platforms); instead, it is socially embedded. As such, technology can include and exclude. Based on this, the opportunities and challenges presented by technology within the higher education system have to be viewed as directly associated with the nature of technology, peoples' attitudes, and culture, among other things.

Concerning industrial revolutions, accelerated economic growth, and social transformation, these are not new to society. The four industrial revolutions are the first industrial revolution in 1765 (was the discovery of coal and its mass extraction, as well as the development of the steam engine and

metal forging); the second industrial revolution in 1870 (the discovery of electricity, gas and oil); the third industrial revolution in 1969 (the introduction of nuclear energy and electronics); and the fourth industrial revolution in 2000 (the acceleration of the Internet and digital technology and renewable energy) (Upkeep Maintenance Management, 2021). Mhlanga & Moloi (2020), citing Davis describe the Fourth Industrial Revolution as the advent of cyber-physical systems building upon the third industrial revolution presenting new opportunities for human-machine integration where technology becomes embedded within societies, including human bodies. It is argued that the world is currently in the fourth revolutionary era, where ICT and a new range of extraordinary technological innovations such AI, robotics, IoT, self-driving cars, three-dimensional (3D) printing, big data analytics and nanotechnology, converge (Sung, 2018). Figure 2 presents the authors' conceptualisation of the Fourth Industrial Revolution and the expected role of higher education.

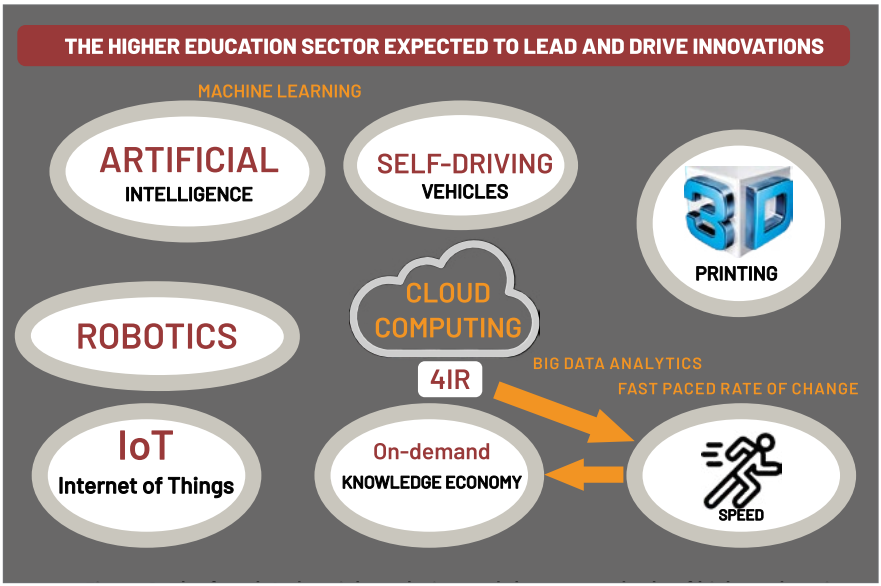

Figure 2: The fourth industrial revolution and the expected role of higher education

Source: *Authors' conceptualisation*

Numerous industry sectors are embracing the Fourth Industrial Revolution globally. Worldwide, trends are shifting towards a technologically driven wave, changing and escalating consumer demands brought about the Fourth Industrial Revolution (Stellenbosch Business School (USB), 2018). The higher education sector is not immune to the influences of the Fourth Industrial Revolution. Although higher education institutions in South Africa have been using technology in blended learning (an integration of face-to-face contact and online learning), the Fourth Industrial Revolution tools were not widely used until the advent of the Covid-19 pandemic which compelled government to impose restrictions on human interactions and the higher education institutions were compelled to shut down campuses as from March 2020. The higher education institutions switched to the digital virtual and remote learning. The Fourth Industrial Revolution technologies used include but not limited to virtual

lessons on television and radio, learning management systems (for example, Moodle, Vula, Blackboard, Web CT, among others) that were zero-rated by service providers (MTN, Vodacom and Telkom). The zero-rated educational websites were based on agreements with the government and institutions. Other Fourth Industrial Revolution tools that became popular include educational applications and cloud live (synchronous) based apps, such as Zoom, Microsoft Teams and Google Meet. Technology-enabled learning and the Fourth Industrial Revolution tools in higher education are expected to be the new normal beyond or post-Covid-19 pandemic bringing about a pedagogical transformation that will benefit the sector. However, owing to uncertainty regarding the impacts of the Fourth Industrial Revolution in the higher education sector in South Africa, its prospects and possible challenges warrant further understanding.

Technology as a pedagogy

Pedagogy can be defined as an art or science of teaching (Bhowmik *et al*., 2013). There is no doubt that the performance of students can be enhanced through excellent teaching informed by pedagogy (Barber & Mourshed, 2007). Although a wide range of teaching strategies are available, there is no single universal approach that seems to fit all contexts. However, one might argue that technology pedagogy is all-encompassing teaching and learning strategy. In the context of this argument, technology pedagogy resembles a range of teaching strategies, including appreciating differences among students, supporting intellectual engagement, and promoting connectedness. However, teaching with technology is a complex practice that involves various interlinking types of focused knowledge (Koehler & Mishra, 2009). Different models are available as a framework to understand, describe, and evaluate the design and implementation of technology-based teaching and learning (Kuriloff, 2005). These frameworks include criteria such as 'programme flexibility, cooperative learning, accommodation of individual differences, learner control, student motivation, and teacher role' (Kuriloff, 2005: 2 citing Reeves). Therefore, a framework for integrating technology-enabled teaching is critical to correctly align various teaching technologies to pedagogy, knowledge and content that adds value to the learning experience.

Results and discussion: prospects technology-enabled teaching and learning in higher education institutions

Improved learner experiences and engagement

One of the common challenges regarding teaching and learning within higher education is that of making the process more interactive and engaging. The ability to learn and acquire cognitive abilities vary considerably among students. Faced with this challenge, getting students to talk (asking or answering questions) is problematic as some of the students are naturally shy and socially confident. Technology in the form of cyber education – online, blended learning offers opportunities for the less confident or shy students to participate by getting their voices heard, for example, through forums (Ascough, 2002; Delmater, 2004). Technology and related Fourth Industrial Revolution tools such as cloud computing also foster collaborative learning opportunities as students' access, share resources and complete learning activities in group discussions at their convenience (Office of Educational Technology, 2017). As such, time and space challenges do not limit student connections. Collaborative learning (group work) opportunity presented by technology through online interactions for students is supported by teaching and learning methods grounded on social constructivism. Students actively

engage in social interactions or explore within their environment (Kay & Kibble, 2016). Therefore, the use of technology brings a paradigm shift from a teacher-centred to a student-centred classroom. Oke and Fernandes (2020), in their study on innovations in teaching and learning: exploring the perceptions of the education sector on the Fourth Industrial Revolution, found that participants were convinced that the use of the Fourth Industrial Revolution – artificial intelligence and analytics in education enhances student experiences, including employability through transformational teaching and learning that is engaging.

Enhancing diversity and student needs

A top-cited challenge in the traditional classroom is the difficulty in diverting attention by a teacher to students' needs (Bester & Brand, 2013). Varying student interests (needs), attitudes and background pose serious challenges. As a result, remedial action is limited to assisting weak or underperforming students. According to the Office of Educational Technology (2017), teachers can use technology for personalised experiences for students. The use of the Fourth Industrial Revolution tools in higher education, such as machine learning (a sub-field of AI), presents opportunities to track and monitor student's performance (Ally & Wark, 2020). Machine learning and AI applications use algorithms. They can be programmed to react and follow ready-crafted heuristics and rules and process historical observations (data records) to predict new patterns, rules, or behaviour. This process can be customised for individual students in higher education. The system learns the students based on data as they progress and can be helpful for educators to make informed decisions to optimize the learning process. For example, at the University of Michigan, teachers use personalised experiences for ensuring students succeed through a support system that uses digital tools such as the ECoach system. The ECoach system provides data analytics, communication, and support to students based on their background, interests/ goals, and performance. Technology such as ECoach allows teachers and faculty to divert attention for individualized needs and coaching to weaker or vulnerable students. This approach closely resembles Kohn's (2004) democratic classroom. Kohn advocates for students' interests and needs to be at the fore to develop curiosity and love of learning from internalised morality. Again, Ascough (2002) argues that online education minimises prejudice concerning the various forms of diversity, such as culture, gender, and race, that are difficult to manage in the traditional classroom. Masinde and Roux (2020), in their study on transforming South Africa's universities of technology: a roadmap through the Fourth Industrial Revolution lenses, show that the adoption of massive open online courses (MOOCs) through off-campus and online teaching and learning not only expands access but being contactless, the real and imagined discrimination of students and staff could be minimised. This transformation of higher education promotes acknowledging and embracing diversity within the higher education spheres.

Fostering multidisciplinary and peer collaborations

Although any educational aim is to develop critical thinking and cultivate their own beliefs and values, traditional education confines students to disciplinary knowledge and content. There has never been a time when interdisciplinary knowledge and international efforts are needed, like in recent times where the world has to contend with complex problems. Educational technologies provide an opportunity to enhance multidisciplinary/ interdisciplinary, intercultural, and international collaborations (Olivier cited in Cloete, 2017). Kayembe and Nel (2019) state that the Fourth Industrial Revolution provides an opportunity for higher education institutions to collaborate with other academics and stakeholders

such as the government, private sector and researchers locally and internationally through cyberspace. The advent of the Fourth Industrial Revolution has seen a rise in cyberspace education. This shift became more prevalent in South Africa during the Covid-19 pandemic. Cyberspace education implies an interactive learning environment/s encompassing multidisciplinary knowledge as opposed to traditional linear learning. Cyberspace education has no frontier boundaries or barriers and is globalised through technology – networks of distance, online or virtual learning.

Cyberspace education offers an opportunity for deep engagement, self-reflection, and expression within the global context on critical issues (Bauman *et al*., 2014). Therefore, technology provides a platform (online) for students to meaningfully engage with other students, experts, and content from other disciplines. The ability to converse in a multidisciplinary context is critical for tackling today's challenges. The plethora of information and ideas available online could challenge students into critical pedagogy and develop the skill of innovative and creative scholars. Again, with a plethora of information, students are challenged to choose wisely from complex inverse data (Bauman *et al*., 2014). Deep learning is possible as the students get to adopt reflective practices as they step beyond disciplinary contexts.

Increased access

Nowadays, along with the transformations taking place in universities, things to do with social justice and widening access are gaining ground. Technology in the higher education sector provides an opportunity to allow access to participants, including those without resources, and adult students, for example, through distance learning (Gumport & Chun, 1999). Xu and Xu (2019) contend that there is no causal evidence to show that online learning increases access for disadvantaged or marginalised groups. However, Xu and Xu (2019) further indicate that online opportunities provide access for temporal flexibility, mid-career or older populations that would not otherwise enrol for traditional programmes due to family and job commitments. Again, technology and cyberspace networks have allowed linkages between students across, local and abroad (beyond bounds of geography). According to Mhlanga and Moloi (2020), access to higher education in South Africa has always been a challenge due to limited space and infrastructure. Mhlanga and Moloi (2020) continue to assert that based on some pockets of excellence to drive the higher education sector in South Africa, the Fourth Industrial Revolution has the potential to increase access.

Similarly, the promise of technology, for example, associated with distance learning is a financial motive. Universities can save money by offering education to students that cannot attend classes due to time or distance constraints. Universities can increase (widen) access, yet the overhead costs will remain the same.

Educational transformation (*pedagogical change*)

In the current era, technology and other Fourth Industrial Revolution tools in higher education are seemingly bringing about educational transformation in higher edcuation. Nowadays, students have access to learning opportunities without time and space barriers (Gumport & Chun, 1999). This benefit is typical for adult students and other students with conflicting priorities such as work and family obligations. Technology enables flexibility in learning anytime and anywhere. Technology has allowed institutions to provide flexible degree pathways outside of the traditional semester-based framework, including programmes and courses with work alternatives, online education, and short courses that

can be engaged remotely. For example, Coetzee *et al*. (2021), citing Wits, indicate that universities in South Africa, such as Wits Graduate School of Business Administration, offer host modules on topics germane to the Fourth Industrial Revolution apart from offering traditional degrees in business or commerce. One such example of a programme is the Master of Management in the field of digital business, encompassing modules in systems thinking, applied big data and analytics, cybersecurity and risk management, digital financial services, digital marketing, among others, relevant for the digital economy.

Also, courses or programmes offered through blended learning, with appropriate instructional design, can promote optimal student interaction and engagement with learning material (VanDerLinden, 2014). For example, Moodle is a powerful LMS platform (a cloud-based – a Fourth Industrial Revolution tool) in teaching and learning to encourage a student-centred learning environment considering that students can readily access the platform on the Internet or network. Via Moodle, many vital resources can be linked and accessed by a group of students. The Moodle platform can be integrated into other search engines, databases, and web resources. Using laptop computers or smartphones connected to the Internet both in and out of the classroom, students can access learning material and resources in real-time (synchronous learning, for example, through the BigBlueButton – a web conferencing tool) or at any given time convenient to the student (asynchronous learning). The ready access to resources such as library resources (e-textbooks) and other learning material and discussion forums represents an active-learning pedagogy. For example, the use of a blog or a forum fosters meaningful interaction with the students. The students can also interact and learn from other students and experts. This is supported by social constructivism (Kay & Kibble, 2016) and connectivism learning theories (Siemens, 2005).

Equipping educators and students with 21st Century skills

There is no denying that world is in the digital era. Technology has become part of the everyday lives of human beings. Therefore, integrating technology in the teaching and learning processes such as navigating and using Moodle platform, for example, both students and teachers continuously learn information literacy skills (Madigan & Sirum, 2006). This is something necessary, especially for the 21st graduate attributes. Some of the most critical skills in the 21st Century include communication, creativity, collaboration, and critical thinking. These skills are also necessary post-education in the future world of work, particularly in the Fourth Industrial Revolution era or the digital economy. Karsten *et al*. (2020), in their study on empowering accounting students to enhance the self-determination skills demanded by the fourth industrial revolution, established some positive attitudes from students concerning the 21st Century skills such as communication and collaboration. Students reported benefitting from the online sessions and activities, although students indicated more desire for practical sessions. Again, Karsten *et al*. (2020) assessed critical thinking by integrated it into other themes that included time management, personal well-being, entrepreneurship, and several social learning activities. Although their findings showed that students had some difficulty with critical thinking and presenting viable solutions to scenario problems, they found that critical thinking was more evident or improved in senior year students.

Suppose students can be empowered or equipped with the critical skills achieved through cyberspace and other Fourth Industrial Revolution tools. In that case, students could achieve the module learning outcomes and value understanding the future world of work. For example, video technology is crucial

for educators designing and integrating student-centred learning in the 21st Century to illustrate processes and concepts. Students can also learn from video technology during the classroom lesson (Brecht, 2012) or after class. Apart from equipping students with information literacy, this is also a form of active and self-directed learning, which resonates with an appropriate pedagogical type of teaching and learning – a flipped classroom model (Roehl *et al*., 2013).

Enabling self-learning and discovery

Bandura's (1977) social learning theory describes learning as a process of constant interaction with the environment. However, of significance in Bandura's emphasis is the concept of self-efficacy – students with a solid sense to have control over their learning, instead of being passively shaped by external forces (McLeod, 2016). In light of this view, technology offers opportunities to enable students to become self-directed students in their quest for self-discovery. Ocholla and Ocholla (2020) envision that if academic libraries in the Fourth Industrial Revolution era are better resourced, accessed and used, they will translate into smart services – library services accessed anytime and virtually everywhere. Ocholla and Ocholla (2020) further state that the Fourth Industrial Revolution and smart modern technologies propagate inclusivity, interlinkage/interconnection, and interdependence of students. This technological shift has the potential to foster self-directed students that are critical thinkers driven by creativity and innovation. Therefore, beyond critical thinking, online technological resources present an opportunity for deep engagement and self-reflection where students can develop their own beliefs and values (Bauman *et al*., 2014).

Reducing administrative burdens

With massification becoming a common challenge in the higher education sector, it also presents administrative burdens. As the numbers of students increase, there is also a need for additional administrative support. For example, in a large classroom setup, it becomes challenging for teachers to mark assessments, provide timely feedback, and keep track of student attendance. Technology, in the form of learning management systems (LMS), such as Moodle and Blackboard, provide a collaborative learning environment for course management. Such networks facilitate the creation of web-based instruction, including marking, monitoring attendance and performance, and timely feedback to students (Attaran *et al*., 2017). Again, ICT and the Fourth Industrial Revolution technologies provide opportunities for developing software packages for convenient management and storage of information, such as backing up teaching and learning tasks in cloud computing, administering examinations, and conducting research (Bagarukayo & Kalema, 2015). Again, the use of AI and machine learning algorithms lessens administrative burdens for educators. It reduces, for example, tedious manual profiling and recording of students, tasks, educational activities and eliminates enormous piles of paperwork associated with traditional teaching and learning methods. In this regard, online pedagogy presents opportunities for educators to engage with their students more conveniently and quickly (Ngubane-Mokiwa & Letseka, 2015). Teachers and students can be connected from all parts of the world at the comforts of their spaces, without administrative, space and time-bound limitations. Again, students are presented with opportunities for unrestricted access to educational materials and resources that eliminate many administrative burdens (Msomi & Bansilal, 2018).

Catering for students with special needs

Technology enables students with special needs to attend and benefit from educational programmes

and activities (Eid, n.d.). Students with special needs, very often are faced with some challenges in higher education. For example, assistive technology or aids, auxiliary aids and services for communication ensure equal opportunity for students with special needs to participate and benefit from the institution's programmes or activities. Another example of helpful technology for otherwise-enabled students is access to electronic versions of textbooks with speech-to-text technology. Therefore, technology in higher education serves otherwise-enabled students and helps to accommodate their needs. The transformational agenda, equity and social justice discourses in higher education advocate that the otherwise-enabled people or students should not be left behind. Assistive technology and devices in the context of the Fourth Industrial Revolution include advanced text-to-speech software and assistive listening systems – designed to help the otherwise enabled students, for example, to read standard print and those with auditory and learning problems, respectively. Besides, advanced assistive technology and devices software programs come with a full range of features that benefit the otherwise-enabled student with a multi-sensory approach to literacy learning. Extra features may include cloud-based support such as multiple text-to-speech voices, multi-language, and dialects, talking spell-checker, picture dictionary graphics, text magnification, tools for taking examinations, ease of notetaking, among many. Ndlovu (2021) used the Critical Disability Theory (CDT) to analyse the provision of assistive technology and assistive devices at an institution of higher education in South Africa and found evidence that assistive technology and devices though not adequately provided in South Africa, enabled students with disabilities' learning.

Reducing costs

Adding to the many problems within the higher education system is the limited access to resources by students and textbook material costs (Stein *et al*., 2017). Some students cannot afford expensive, prescribed textbooks. Given the few textbook resources available at disadvantaged institutions versus the high number of students competing for the same resource, other students are at risk of missing valuable course content/ material. The Internet of Things, a Fourth Industrial Revolution technology that refers to the interconnectedness of objects or computing devices and their ability to communicate/transfer data via a network, has seen the integration of machine learning, big data, machine-to-machine communication, and automation in almost every industry, including the higher education sector. IoT smart objects or machines are more efficient than human beings in processing and delivering services. The IoT is critical in any industry as it facilitates information-sharing (Olaitan et al., 2021). Therefore, A.I. (a Fourth Industrial Revolution technology) would significantly reduce the cost of goods and services and increase the accessibility of learning material to students and educators alike in higher education.

Also, using digital platforms for cyberspace education like Moodle technology amount to opportunities to transform or ease the access to learning material such as digital resources (open access e-books) by students at a low cost. Digital resources and the use of, for example, cloud-based collaboration systems improve information sharing (Sawas, & Watfa, 2015). Learning material can be made available to students at low cost, to many students at the same time, or beyond the classroom at any time.

Facilitating and enhancing assessments

In the context of increasing (large) classes, conducting assessments is limited (Daniel *et al*., 2010). Appropriate management of assessment is critical for fostering and checking learning progress.

Technology presents an opportunity for assessment to be linked to formative learning activities that deviate from the norm (traditional examination/ tests) and assist students in learning if correctly used. For example, advanced analytics and data-rich formative assessments provide feedback immediately to students and teachers (Ifenthaler *et al*., 2018). The feedback can assist students towards mastery, participation in discussions (online forums), project-based learning, games, and simulations. Some of the tools provide a platform for peer learning through revision. Ramra and Marimuthu (2019) researched the impact of technology in expediting learning: a South African experience and noted that online assessments such as surveys, discussion forums, blogs, videos, and other cyber tools were stated as beneficial in expediting the learning experience. Also, Ramra and Marimuthu (2019) argue that new and innovative assessment methods are possible and endless with technology, thereby contributing to creative, authentic and student-centred education that encourages critical thinking, student engagement, and collaborative learning.

Results and discussion: challenges of using technology in teaching and learning in higher education institutions

The commodification of knowledge and education

The term 'knowledge economy' has become popular to describe the inextricable link between education and the economy in recent times (Cloete, 2017). Some also view this linkage as an ideology of capitalism. Cloete (2017:3), citing the World Bank, defines a knowledge-based economy as one that '... relies primarily on the use of ideas rather than physical abilities and the application of technology.' The emphasis is on the rapid change, the need and demand for skilled workers and lifelong learning with technology being an integral part of education. However, Amory, cited in Cloete (2017), argues that those who advocate for technology promotion in the knowledge-based economy foster the neo-liberal agenda of power, commercialisation and profit-making. Such neo-liberal markets where technology is central tend to be instructive. The argument put forward by Amory (2012) is that this has caused a shift in universities from the business of education (offering quality education) to the education business (profit-making), a customer-client relationship (with no learning occurring). Margarita and Homa (2020), in their study on digitalization, education and skills development in the global South: An assessment of the debate with a focus on Sub-Saharan Africa, concludes that some noted risks of digitalisation education are its potential to erode the very idea of education, benefitting the private sector, where the employability aspect outweighs social and cultural values.

Increasing costs

Despite the notion that technology can reduce costs in higher education, on the contrary, Martin (2007) contends that ICT in higher education can potentially increase costs. Martin (2007) believes that the commodification of education, mainly driven by profit-making, only benefits the technology sellers. Universities and other higher education institutions tend to invest more in technology infrastructure (including software) and have less budget to appoint new staff, development, and training. Therefore, in the face of shrinking funding, universities find new ways to fund teaching and research. One obvious way is transferring the costs to students – increasing student fees. In the context of the Fourth Industrial Revolution, for new technology to thrive in higher education institutions, there is a need for funding and investment in Fourth Industrial Revolution research. Due to dwindling funding in the higher education sector, the situation may reduce research funding on the Fourth Industrial

Revolution, critical for its implementation and policy. Kayembe and Nel (2019) noted lack of funding as a primary challenge in higher education in South Africa concerning the implementation of the Fourth Industrial Revolution. To invest in new Fourth Industrial Revolution technological advancements and developments, universities and institutions of higher education end up increasing student fees. In that context, prioritising and investing in the Fourth Industrial Revolution in the higher education sector can increase costs, adding to the existing problem of lack of funding in the sector. Also, Moeketsi *et al*. (2018) and Madge *et al*. (2019) indicate that online technologies and the Internet are costly, especially the cost of data (bandwidth) in South Africa.

Creating and exacerbating the digital divide

The problem brought about by technology in a knowledge-based economy is the dual challenge of access and literacy for a developing country such as South Africa (World Bank, 2003). Many South Africans do not have access to technology infrastructure, such as network (bandwidth), yet those with access might not have a quality network. The digital divide challenge presented by technology is not only that of physical access but also epistemological, where both students and teachers (lagging) are required to be technologically privy (computer literate) (Cloete, 2017). Therefore, the push towards the use of technology, for example, online education in South Africa, where not everyone has access, could exacerbate inequality.

Czerniewicz *et al*. (2020), in their study titled 'A Wake-Up Call: Equity, Inequality and Covid-19 Emergency Remote Teaching and Learning', state that one of the biggest threats associated with virtual/remote learning is digital fluency for both staff and students. Czerniewicz *et al*. (2020) found that digital literacies were a concern and an equity barrier. For example, in the advent of the Covid-19 pandemic, academics and students were expected to shift and participate almost virtually in all educational tasks in cyberspace education literally without any training. It became apparent that the digital divide is a barrier concerning participation in cyberspace education in the context of the Fourth Industrial Revolution. Although most higher education institutions in South Africa are increasingly providing some infrastructure such as Wi-Fi on campuses, Ng'ambi *et al*. (2016) raises some concern that not all students can afford decent laptops. Reliable bandwidth, access or laptop/notebook devices and other network or cyberspace infrastructure are necessary to operate in the Fourth Industrial Revolution. This situation seems to be a challenge in a highly unequal South Africa, particularly for the historically disadvantaged institutions.

Technology becoming an end in itself rather than a means to an end

It is argued that in this digital era, millennials tend to view technology as an end in itself. Although technology in the form of online education, for example, provides enhanced access and flexibility in learning, Cloete (2017), citing Chau, argues that it is not always valued the same as traditional (residential) training. Cloete (2017) demonstrates this by a survey conducted by Adams and De Fleur that established that employers prefer applicants with traditional training qualifications to online courses/ degrees. Interestingly, the same study confirmed that higher education institutions were reluctant to accept candidates who had an online qualification/s for enrolment to their degree programmes.

As already discussed, scholars, for example, Moonsamy and Govender (2018) and Motala and Menon (2020), agree that some students at higher education institutions lack adequate coping strategies

for online learning platforms. Higher education institutions should ensure that meaningful learning is attained to promote a conducive online teaching and learning community. Patrick *et al*. (2021) caution that there could be a tendency to conclude academic sessions or activities in cyberspace education without necessarily culminating into meaningful knowledge (Table 2). Therefore, the responsibility is for institutions to provide guidelines and tutorials to equip students how to effectively use the online platforms and the Fourth Industrial Revolution learning tools for active and engaging learning. Patrick *et al*. (2021), citing Bozalek & Ng'ambi, further suggest that meaningful learning could be attained through measuring or evaluating tasks with learning outcomes and teaching strategies. In light of this, technology should not drive instruction – nor should technology be viewed as a substitute for instruction.

Cybersecurity risks

Although technology is making strides in all spheres of life, concerns related to cybersecurity, privacy, data confidentiality and ethics are rising (Coetzee *et al*., 2020). A significant challenge in using technology in the context of the Fourth Industrial Revolution includes network and data security, compliance, and governance concerns (Attaran *et al*., 2017). The top three cited primary security issues facing institutions concerning cloud services are legal issues, compliance, and loss of control over data (Gonzalez *et al*. cited in Attaran *et al*., 2017).

Therefore, an increase in the use of online technologies (cloud computing) by universities in the teaching and learning processes implies that more expertise and training in information technology (IT) development and security will be critical. Attaran *et al*. (2017) contend that technology, such as cloud infrastructure to some degree, is an open shared resource, subject to cyber attackers. Therefore, educational technology exposes users to malicious attacks such as identity hijacking and distribution of malicious code from both insiders and outsiders. Management of security in educational technology is, therefore, paramount. Again, there are increasing concerns requiring curricula to be adjusted to equip graduates with skills to adhere to ethical conduct and related standards in the workplace in the context of shifting the Fourth Industrial Revolution demands.

Depriving the human and social elements in learning

One of the challenges associated with technology (for example, mobile devices) in education may include distractions, disorderliness, and noise levels if rules are not adequately maintained (Fang, 2009). Pather (2020) mention that a critical driver in the Fourth Industrial Revolution-education is the social media revolution. Social media platforms including Facebook, Twitter, and WhatsApp had become widely used for virtual and online learning, particularly in the advent of the Covid-19 pandemic when national lockdowns were instituted at the beginning of March 2020. Social media platforms have significantly changed the communication methods within the higher education sector. Other groups, such as adult students, might find mobile devices and social media distracting. Pather (2020) further cautions that these technologies should be used with care in teaching and learning.

Again, various sorts of distractions from technology use in the classroom may range from computer (laptop) usage, phone ringing, and online (for example, WhatsApp) chatting, among others (Guliz & Koç, 2015). Such disturbances have the potential to affect the teacher and other students' attention in class. Informed by the behaviourism approach, one can do away with the problem of undesirable behavioural issues. Establishing ground rules at the beginning of the semester or term with the

students could help model appropriate/good behaviour. This is supported by Kohn's (2004) theory of a democratic classroom community and management.

Again, Janse van Rensburg (2018), in the study of effective online teaching and learning practices for undergraduate health sciences students noted that some students had negative experiences concerning cyberspace education from peers' non-constructive feedback. Janse van Rensburg (2018) also found that other students viewed some of their peers' argumentative posts as not conducive to learning. Janse van Rensburg (2018) further states that interpretation of online communication without video or auditory interface as in face-to-face contact could be difficult for some students.

Un- or under-preparedness of both teachers and students

In the current digital era, teachers,' and students' basic literacy to access and evaluate information critically is inadequate to support society's complex needs. There is growing leverage for strategic technologies that promote critical thinking and complex problem-solving (Kent & Moore, 2014). This situation calls for the increasing demand for instructional design expertise due to changing learning models and the growing need to measure and evaluate learning. Instructional design refers to a more nuanced skill of delivering content by teachers to students in a meaningful manner that combines knowledge co-creation with evolving technologies and competencies beyond digital fluency (Kanuka, 2006). The instructional design allows teachers to communicate effectively and critically, be innovative, and make informed problem-solving decisions. Therefore, the use of technology in higher education implies a growing demand for expertise in the development and implementation of adaptive learning, competency-based learning, and other digital learning innovations.

Generally, the situation in the Sub-Saharan African region lacks readiness for the age of digitalization concerning adequate infrastructure and lack of skills. Tilya (2018) noted that the upscaling, coordination, systematisation, and sustainability of digitalization education remain challenging. Therefore, the Fourth Industrial Revolution poses a challenge to teachers and instructional designers as learning and attitude towards technology change quickly (Liu *et al*., 2002). Institutions will have to invest in instructional designers who will work with teachers to create rigorous, high-quality programming to serve the students' needs. Indeed, Penprase (2018) contends that more proactive and creative forms of faculty development are critical to enabling faculty to adapt and maintain itself within the fast-paced environment in the Fourth Industrial Revolution era.

Difficulty quality assuring and regulating learning

Although there is massive loads of material and information available on the Internet, in the form of free online resources, making learning more accessible, free, and open is not enough (Noble, 2004). In the Fourth Industrial Revolution era, distance learning will become more prevalent. Mahlangu (2018) highlights that one of the pertinent challenges noted in higher education concerning distance-learning settings is quality assurance issues Again, Bagarukayo and Kalema (2015), citing Isabirye and Dlodlo indicate a lack of policy and management and non-integration of online strategy as a challenge to implementing cyberspace education in South Africa.

Learning material delivered online must be credible and should meet quality thresholds. Regulating high-quality content available online is not easy. One difficulty is the accreditation and trust associated with online courses. In contrast, traditional (residential) higher education institutions are deemed to

be credible. Again, with so much information out there, regulating bad practices such as cheating and plagiarism becomes difficult (Jereb et al., 2018). However, other technologies become handy in controlling and monitoring, for example, plagiarism such as similarity checking software (like Turnitin.com) and teaching students to acknowledge sources appropriately.

Increasing costs of electricity and inadequate infrastructure in rural areas

In the Fourth Industrial Revolution era, students and educators alike need access to technological resources. These resources include physical devices, teaching and learning wearables and simulation software packages such as but not limited to netbooks, iPads, webcams, laptops and desktop computers, mobile phones, networking devices and others. Although some of these resources are powered by battery power, they mainly depend on electricity for sustained use and recharging. However, some rural areas in South Africa do not have reliable networks and electricity infrastructure (Mhlanga, 2020). Indeed, Bharuthram and Kies (2013) indicate that several South African higher education students are disadvantaged. Those in rural areas battle with socio-economic hardships, including having no access to basic facilities such as electricity. Vukosi et al. (2021) also reported that besides the lack of infrastructure in South Africa, the rising electricity costs had sparked general affordability concerns. The current load shedding is also worsening the electricity issue by Eskom – a South African electricity public utility, established in 1923 as the Electricity Supply Commission.

Conclusion

Technology-enabled teaching and learning are becoming widely embraced by higher education institutions. This paper has discussed the opportunities and challenges of integrating technology as a pedagogy in South African higher education institutions. Although there can be some challenges in using technology in teaching and learning, undoubtedly integrating a carefully designed and thought through technology in the teaching and learning processes benefit students. Technology provides opportunities for using the classroom time for more interactivity (actively engaging students), student collaboration, self-directed learning, and solving problems in a fun, creative and innovative manner. Technology also promises to overcome some of the issues unintentionally presented through a traditional classroom. However, the use of technology in higher education also presents some challenges that will need to be considered and managed. These include lack of access and literacy for digital resources (digital divide), cybersecurity issues, difficulty regulating bad practices, and rising electricity costs. Others also contend that neo-liberalists advocate the use of technology for profit-making and the commodification of education. As technology can be disruptive, if appropriate technologies are carefully chosen, accessible and affordable, we take it that it can benefit the higher education sector in South Africa and the challenges it poses can be minimized or dealt with.

It is important that higher education institutions explore options for the challenges discussed in this paper so that the use of technology in teaching and learning realises its full potential, and provides optimal benefits to students, teachers, higher education institutions and society at large.

References

Ally, M. & Wark, N. (2020). *Sustainable Development and Education in the Fourth Industrial Revolution*. Burnaby, British Columbia: Commonwealth of Learning

Amory, A. (2012). Instructivist ideology: Education technology embracing the past? *Interactive Learning Environments*, 20(1): 41-5

Ascough, R.S. (2002). Designing online distance education: Putting Pedagogy before technology. *Teaching Theology and Religion* 5(1): 17-2

Attaran, M., Attaran, S., & Celik, BG (2017). Promises and Challenges of Cloud Computing in Higher Education: A Practical Guide for Implementation. *Journal of Higher Education Theory and Practice*, 17(6): 20-38.

Azeez, N.A., & Van Der Vyver, C. (2018). Digital Education: Assessment of e-Learning and m-Learning Adoption in Higher education institutions in South Africa. 2018 IEEE Conference on e-Learning, e-Management and e-Services (IC3e), Langkawi, Malaysia, November 21–22, 2018, pp. 23–28

Bandura, A. (1977). *Social Learning Theory*. Englewood Cliffs, NJ: Prentice Hall

Bagarukayo, E., & Kalema, B. (2015). Evaluation of e-Learning usage in South African universities: A critical review. *International Journal of Education and Development using Information and Communication Technology*, 11(2):168–18

Barber, M., & Mourshed, M. (2007). *How the World's Best Performing School Systems Come Out on Top*. London, McKinsey & Company

Barbier, J., Cevenini, P., & Crawford, A. (2012). Video solves key challenges in higher education [Cisco white paper]. San Jose, CA: Cisco

Bester, G., & Brand, L. (2013). The effect of technology on learner attention and achievement in the classroom. *South African Journal of Education*, 33(2):1-15

Bharuthram, S., & Kies, C. (2013). Introducing e-learning in a South African Higher Education Institution: Challenges arising from an intervention and possible responses. *British Journal of Educational Technology*, 44(3): 410–420

Bhowmik, M., Banerjee, B.R., & Banerjee, J. (2013). Role of Pedagogy in Effective Teaching. *Basic Research Journal of Education Research and Review*, 2(1): 01-05

Bauman, W., Marchal, J.A., Mclain, K., O'Conneil, M., & Patterson, S.M. (2014). Teaching the millennial generation in the religious and theological studies classroom. *Teaching Theology and Religion*, 17(4): 301-322

Brecht, H.D. (2012). Learning from online video lectures. *Journal of Information Technology Education: Innovations in Practice*, 11, 227–250

Cleveland-Innes, M., Gauvreau, S., Richardson, G., Mishra, S.; & Ostashewski, N. (2019). Technology-Enabled Learning and the Benefits and Challenges of Using the Community of Inquiry Theoretical Framework. *International journal of E-Learning & Distance Education*, 34(1):1-1

Chandarman, R., & Van Niekerk, B. (2017). Students' cybersecurity awareness at a private tertiary educational institution. *The African Journal of Information and Communication (AJIC)*, 20: 133-15

Cloete, A.L. (2017). Technology and education: Challenges and opportunities. *Herv. teol. stud*., 73(4):1-

Coetzee, J., Neneh, B., Stemmet, K., Lamprecht, J., Motsitsi, C., & Sereeco, W. (2021). South African universities in a time of increasing disruption. *South African Journal of Economic and Management Sciences* 24(1), a3739. https://doi.org/10.4102/sajems.v24i1.3739

Czerniewicz, L., Agherdien, N., Badenhorst, J., Belluigi, D., Chambers, T., Chili, M., de Villiers, M., Felix, A., Gachago, D., Gokhale, G., Ivala, E., Kramm, N., Madiba, M., Mistri, G., Mgqwashu, E., Pallitt, N., Prinsloo, P., Solomon, K., Strydom, S., Swanepoel, M., Waghid, F., & Wissing, G. (2020). A Wake-Up Call: Equity, Inequality and Covid-19 Emergency Remote Teaching and Learning. *Postdigit Sci Educ*, 2: 946–967

Daniel, E., Shanthi, A., Matiu, R., Susan, M., Martin, D., Dennis, H., & Rod, J. (2010). Student Engagement in Very Large Classes: The Teachers' Perspective. *Studies in Higher Education*, 35: 761-775

Delmater, S. (2004). A typology of the use of technology in theological education. *Teaching Theology and Religion*, 7(3):134-14

Department of Higher Education and Training (DHET) (2001). Draft national plan for higher education in South Africa. (Online) Available: http://www.dhet.gov.za/HED%20Policies/National%20Plan%20on%20Higher%20Education.pdf. [Retrieved on 08 July 2021]

Drees, W.B. (2002). Human meaning in a technological culture: Religion in an age of technology. *Zygon,* 37(3): 597-604

Eid, N., (n.d.). Innovation and technology for persons with disabilities. (Online) Available: https://www.un.org/esa/socdev/egms/docs/2013/ict/innovation-technology-disability.pdf [Retrieved on 26 September 2019]

Fang, B. (2009). From distraction to engagement: Wireless devices in the classroom. *Educause Quarterly*, 32(4): 1-1

Fataar, A. (2020). The emergence of an education policy dispositive in South Africa: An analysis of educational discourses associated with the fourth industrial revolution. *Journal of Education (University of KwaZulu-Natal)*, (80): 5-24

Food and Agriculture Organisation (FAO), 2015. Climate change and food security: risks and responses. (Online) Available: http://www.fao.org/3/i5188e/i5188e.pdf [Retrieved on 08 July 2021]

Garrison, D.R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education model. *The Internet and Higher Education*, 2(2-3): 87-10

Gleason N.W. (2018). Singapore's Higher Education Systems in the Era of the Fourth Industrial Revolution: Preparing Lifelong Learners. In: Gleason N. (eds) *Higher Education in the Era of the Fourth Industrial Revolution*. Singapore: Palgrave Macmillan

Gumport, P.J., & Chun, M. (1999). *Technology and Higher Education: Opportunities and Challenges for the New Era.* National Centre for Postsecondary Improvement (NCPI) Technical Report Number 1-02: Stanfor

Henry, M., Gibson, D.C., Flodin, C., & Ifenthaler, D. (2018). Learning innovations for identifying and developing talent for university. In: Dominique Parrish, D., Joyce-McCoach, J. (eds) Innovations *in Higher Education – Cases on Transforming and Advancing Practice*. London: IntechOpen

Hess, M.E. (2002). Pedagogy and theology in cyberspace: "All that we can't leave behind..." *Teaching Theology and Religion*, 5(1): 30-38.

Howard, P., O'Brien, C., Kay, B., & O'Rourke, K. (2019). Leading Educational Change in the 21st Century: Creating Living Schools through Shared Vision and Transformative Governance. *Sustainability* 2019, 11, 4109; doi:10.3390/su11154109

Ifenthaler, D., Greiff, S. & Gibson, D. (2018) Making Use of Data for Assessments: Harnessing Analytics and Data Science. In: Voogt, J., Knezek, G., Christensen, R., Lai, K.W. (eds) *Second Handbook of Information Technology in Primary and Secondary Education*. Springer International Handbooks of Education. Springer, Cham

Janse van Rensburg, E.S. (2018). Effective online teaching and learning practices for undergraduate health sciences students: An integrative review. *International Journal of Africa Nursing Sciences*, 9(2018): 73-80

Jereb, E., Perc, M., Lämmlein, B., Jerebic, J., Urh, M., Podbregar, I., & Šprajc, P. (2018). Factors influencing plagiarism in higher education: A comparison of German and Slovene students. *PloS one*, 13(8): 1-16

Kanuka, H. (2006). Instructional design and e-learning: A discussion of pedagogical content knowledge as a missing construct. *The e-Journal of Instructional Science and Technology*, 9(2): 1-17

Karsten, I., van der Merwe, M., & Steenekamp, K. (2020). Empowering Accounting Students to Enhance the Self-Determination Skills Demanded by the Fourth Industrial Revolution. *South African Journal of Higher Education*, 34(2): 36–58.

Kay, D. & Kibble, J. (2016). Learning theories 101: application to everyday teaching and scholarship. *Adv Physiol Educ*, 40: 17–25

Kayembe, C., & Nel, D. (2019). Challenges and Opportunities for Education in the Fourth Industrial Revolution. *African Journal of Public Affairs*, 11:79-94

Kent, A.M., &Moore, C.D. (2014). Critical Thinking and Problem Solving: Can Technology Be a Tool? It's as Simple as IVC! *International Journal of Learning, Teaching and Educational Research*, 8(1).

Khoza, S.B. (2012). Who helps an online facilitator to learn with students in a day? *Mevlana International Journal of Education (MIJE)*, 2(2), 75-84

Koehler, M.J., & Mishra, P. (2009). What Is Technological Pedagogical Content Knowledge? Contemporary Issues in Technology and Teacher Education, 9(1). Online) Available: https://www.citejournal.org/volume-9/issue-1-09/general/what-is-technological-pedagogicalcontent-knowledge/ [Retrieved on 26 September 2019]

Kolb, D.A. (1984). *Experiential Learning: Experience as the Source of Learning and Development, Up Saddle River*, NJ: Financial Times Prentice Hall

Kohn, A. (2004). *What does it Mean to be Well Educated?* Boston: Beacon Press.

Kuriloff, P. (2005). Breaking the barriers of time and space: More effective teaching using e-pedagogy. *Innovate,* 2 (1)

Liu, M., Gibby, S., Quiros, O., & Demps, E. (2002). The Challenge of Being an Instructional Designer for New Media Development: A View from the Practitioners. *Journal of Educational Multimedia and Hypermedia*. 11

Lyner-Cleophas, M. (2019). Assistive technology enables inclusion in higher education: The role of Higher and Further Education Disability Services Association. *African Journal of Disability* (Online), 8: 1-6

Madigan, D., & Sirum, K.L. (2006). Enabling Interactive Engagement Pedagogy Through Digital Technology. *Innovation in Teaching and Learning in Information and Computer Sciences*, 5(4): 109-121

Madge, C., Breines, M.R., Dalu, M.T.B., Gunter, A., Mittelmeier, J., Prinsloo, P., & Raghuram, P. (2019). WhatsApp use among African international distance education (IDE) students: transferring, translating and transforming educational experiences. *Learning, Media and Technology*, 44(3): 267-282

Mahlangu, V. P. (2018). The good, the bad, and the ugly of distance learning in higher education. In: Sinecen, M. (eds), *Trends in E-learning*. IntechOpen. https://doi.org/10.5772/intechopen.75702.

Malik, A., & Chaudhry, M. (2014). Intersection of Pedagogy and Emerging Technologies to Enhance Student-Centred Learning in Higher Education. *Pakistan Journal of Social Sciences*, 34: 397-407

Mamphiswana, R., & Bekele, M. (2020). The Fourth Industrial Revolution: Prospects and Challenges for Africa. Proceedings of the International Association for Management of Technology (IAMOT) 2020 Conference, Cairo, Egypt, 13 – 17 September 2020, pp. 1-12

Margarita, L., & Homa, B. (2020). Digitalization, education and skills development in the global South: An assessment of the debate with a focus on Sub-Saharan Africa, ÖFSE Briefing Paper, No. 28. Austrian Foundation for Development Research (ÖFSE), Vienna

Martin, R. (2007). Online education and training: Well-founded pedagogy or state corporate interest? *South African Journal of Higher Education,* 21(3): 473-484

Mashau, P., & Nyawo, J.C. (2021). The use of an online learning platform: a step towards e-learning. *South African Journal of Higher Education*, 35(2): 123–143

Masinde, M., & Roux, P.A. (2020). Transforming South Africa's Universities of Technology: A Roadmap Through the Fourth Industrial Revolution Lenses. *Journal of Construction Project Management and Innovation*, 10(2): 30-50

Mayisela, T. (2014). Assessing How E-learning Implementation has Enhanced the Lecturers' Teaching Practices at a South African University. *International Journal of Educational Sciences*, 6(1): 117-124

Meyer, I.A. & Gent, P.R. (2016). The Status of ICT in Education in South Africa and the Way Forward. Centurion: The National Education Collaboration Trust (NECT). (Online) Available: https://nect.org.za/publications/technical-reports/the-state-of-ict-in-education-in-south-africa/@@download/file/The%20State%20of%20ICT%20in%20Education%20In%20South%20Africa.pdf [Retrieved on 10 July 2021].

Mhlanga, D. (2020). Industry 4.0: The Challenges Associated with the Digital Transformation of Education in South Africa. In: Aydın, O. (eds) *The Impacts of Digital Transformation* (pp. 13-26). Instanbul: Efe Academy

Mhlanga, D. & Moloi, T. (2020). COVID-19 and the Digital Transformation of Education: What Are We Learning on the Fourth Industrial Revolution in South Africa? *Educ. Sci.*, 10, 180; doi:10.3390/educsci10070180

Moeketsi L., Matsephe, M.L., Victor P. (2018). The Challenges of E-learning in South Africa. In: Sinecen, M. (eds), *Trends in E-learning*. IntechOpen. DOI: 10.5772/intechopen.74843

Moonsamy, D., & Govender, I. (2018). Use of blackboard learning management system: An empirical study of staff behavior at a South African university. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(7): 3069–3082

Motala, S., & Menon, K. (2020). In search of the "new normal": Reflections on teaching and learning during Covid-19 in a South African university. *Southern African Review of Education*, 26(1), 80–99.

Mpungose, C.B. (2020). Emergent transition from face-to-face to online learning in a South African University in the context of the coronavirus pandemic. *Humanities and Social Sciences Communications*, 7(1): 1–9

Msomi, A.M.; & Bansilal, S. (2018). The experiences of first-year students in mathematics in using an e-learning platform at a university of technology. *South African Journal of Higher Education*, 32(5):124–129

Naudé, W. (2027). *Entrepreneurship, Education and the Fourth Industrial Revolution in Africa*. Discussion Paper Series (IZA DP No. 10855). Bonn, Germany: Institute of Labor Economics

Ndlovu, S. (2021). Provision of Assistive Technology for Students with Disabilities in South African Higher Education. *Int. J. Environ. Res. Public Health*, 18: 3892. https://doi.org/10.3390/ijerph18083892

Ng'ambi, D. Brown, C., Bozalek, V., Gachago, D., & Wood, D. (2016). Technology enhanced teaching and learning in South African higher education - A rearview of a 20-year journey: 20 years reflection on technology enhanced learning. *British Journal of Educational Technology*, 47(5): 1-22

Ngubane-Mokiwa, S., & Letseka, M. (2015). Shift from open distance learning to open distance e-learning. In M. Letseka (ed.), *Open distance learning (ODL) in South Africa*, pp. 129–142, Nova Publishers, New York, NY

Noble, D.F. (2004). Assessing the Reliability of Open-Source Information. (Online) Available: http://arnoreuser.com/wp-content/papercite-data/pdf/noble2004.pdf [Retrieved on 26 September 2019].

Ocholla, D.N., & Ocholla, L. (2020). Readiness of academic libraries in South Africa to research, teaching and learning support in the Fourth Industrial Revolution. *Library Management*, 41(6/7): 355-368

Office of Educational Technology (2017). Reimagining the Role of Technology in Higher Education: A Supplement to the National Education Technology Plan. (Online) Available: https://tech.ed.gov/files/2017/01/Higher-Ed-NETP.pdf [Retrieved on 26 August 2019]

Oke, A., & Fernandes, F.A.P. (2020). Innovations in Teaching and Learning: Exploring the Perceptions

of the Education Sector on the 4th Industrial Revolution (the Fourth Industrial Revolution). J*. Open Innov. Technol. Mark. Complex*, 6, 31. doi:10.3390/joitmc6020031

Olaitan, O.O., Issah, M., & Wayi, N. (2021). A framework to test South Africa's readiness for the fourth industrial revolution. *South African Journal of Information Management*, 23(1), a1284. https://doi.org/10.4102/sajim.v23i1.1284

Oliver, W.H. (2020). Teaching theology in the Fourth Industrial Revolution. *HTS Teologiese Studies/ Theological Studies*, 76(2), a5940. https://doi.org/10.4102/hts.v76i2.5940

Pather, M.R. (2020). The Impact of the Fourth Industrial Revolution on Education in South Africa. *Education and the Fourth Industrial Revolution*, 83:19-23

Pather, S., Booi, E., & Pather, S. (2020). An assessment of student resource readiness for online learning during Covid 19: A South African case study. Proceedings of ICERI2020 Conference, 9th-10th November 2020, pp. 9753-9762

Patrick, H.O., Abiolu, R.T.I., & Abiolu, O.A. (2021). Reflections on COVID-19 and the viability of curriculum adjustment and delivery options in the South African educational space. *Transformation in Higher Education*, 6(0), a101. https://doi.org/10.4102/the.v6i0.101

Penprase B.E. (2018). The Fourth Industrial Revolution and Higher Education. In: Gleason N. (eds) *Higher Education in the Era of the Fourth Industrial Revolution*. Palgrave Macmillan, Singapore

Queiros, D.R., & de Villiers M.R. (2016). Online Learning in a South African Higher Education Institution: Determining the Right Connections for the Student. *International Review of Research in Open and Distributed Learning*, 17(5):165-185

Ramra, U., & Marimuthu, F. (2019). The Impact of Technology in Expediting Learning: A South African Experience. EBEE'19: Proceedings of the 2019 International Conference on E-Business and E-commerce Engineering, December 2019, pp. 35–40. https://doi.org/10.1145/3385061.3385065

Roehl, A., Reddy, S.L., & Shannon, G.J. (2013). The flipped classroom: an opportunity to engage millennial students through active learning strategies. *Journal of Family and Consumer Sciences*, 105: 44–49

Roodt, J.H., & Koen, H. (2020). *A Review of Hurdles to Adopting Industry 4.0 in Developing Countries*. INCOSE International Symposium, 30(1), 1079-1092. https://doi.org/10.1002/j.2334-5837.2020.00773.x

Sawas, M.S. & Watfa, M.K. (2015). The impact of cloud computing on information systems agility. *Australasian Journal of Information Systems*, 19: 97-112

Siemens, G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning, 2(1). (Online) Available: http://itdl.org/journal/jan_05/article01.htm [Retrieved on 27 June 2019]

Skinner, B.F. (1976). *About Behaviorism*. New York: Vintage Books

Stein, S., Hart, S., Keaney, P., & White, R. (2017). Student views on the cost of and access to textbooks: An investigation at University of Otago (New Zealand). *Open Praxis*, 9(4): 403-419

Sung, J. (2018). *The Fourth Industrial Revolution and Precision Agriculture. In: Hussmann, S. (Eds.)*

Automation in Agriculture - Securing Food Supplies for Future Generations. London: Intechopen https://doi.org/10.5772/intechopen.71582

Tilya, F. (2018). Information and Communication Technology and Educational Policies in the Sub-Saharan African Region. In: Voogt, J./Knezek G. (eds.) *Handbook of Information Technology in Primary and Secondary Education*. 1145-1161

Tjønneland, E.N. (2017). Crisis at South Africa's universities – what are the implications for future cooperation with Norway? *CMI Brief*, 16(3): 1-4

Ugur, N.G., & Koç, T. (2015). Mobile Phones as Distracting Tools in The Classroom: College Students Perspective. *Alphanumeric Journal*. 3. 10. 17093/aj.2015.3.2.5000145549

Upkeep Maintenance Management (2021). What Are the 4 Industrial Revolutions? (Online) Available: https://www.onupkeep.com/answers/maintenance-history/four-industrial-revolutions [Retrieved on 08 July 2021].

UNESCO-IESALC (2020). Towards universal access to higher education: international trends. (Online) Available: https://www.iesalc.unesco.org/en/wp-content/uploads/2020/11/Towards-Universal-Access-to-HE-Report.pdf [Retrieved on 08 July 2021].

United Nations (U.N.) (2020). World Social Report 2020: Inequality in a Rapidly Changing World. (Online) Available: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/01/World-Social-Report-2020-FullReport.pdf [Retrieved on 08 July 2021]

Stellenbosch Business School (USB) (2018). The future of the Western Cape's agriculture in the context of the Fourth Industrial Revolution. (Online) Available: https://www.usb.ac.za/usb_reports/the-future-of-the-western-capes-agriculture-in-the-context-of-the-fourth-industrial-revolution/ [Retrieved on 09 May 2021]

VanDerLinden, K. (2014). Blended Learning as Transformational Institutional Learning. *New Directions for Higher Education*, 165: 75-85

Venter P., van Rensburg, M.J., & Davis, A. (2012). Drivers of learning management system use in a South African open and distance learning institution. *Australasian Journal of Educational Technology*, 28(2): 183–198

Vukosi, M., Aghoghovwia, P., Ismail, Y., Mahomed-Asmail, F., & Steenhuisen, S. (2021). The Fourth Industrial Revolution - what does it mean to our future faculty? *South African Journal of Science*, 117(5-6): 1-3.

World Bank (2003). *Lifelong Learning in the Global Knowledge Economy: Challenges for Developing Countries*. World Bank, Washington, DC

Xing, B & Marwala, T. (2017). Implications of the Fourth Industrial Age for Higher Education. The Thinker, 73 (Third Quarter 2017): 10-15. https://ssrn.com/abstract=3225331

Xu, D. & Xu, Y. (2019). *The Promises and Limits of Online Higher Education; understanding how distance education affects access, cost, and quality*. Irvine: American Enterprise Institute (AEI)

Zimba, Z.F., Khosa, P., & Pillay, R. (2020). Using blended learning in South African social work education to facilitate student engagement. *Social Work Education*, 40(2): 263–278

A Reflection of Artificial Intelligence in South African Higher Education

N. Pillay

Department of Computer Science

University of Pretoria

nelishia.pillay@up.ac.za

Abstract

Artificial intelligence has had a major impact on the business, health, agriculture and education sectors worldwide by automating various processes resulting in reduced workloads and improved economic development. This paper is a position paper firstly examining these advancements of artificial intelligence in higher education internationally. Major contributions include intelligent tutoring systems, learning analytics and educational data mining, automated marking, student support for student wellness and wellbeing. The paper also looks at the skills shift that artificial intelligence has brought with it and the impact this has on curriculum development in South African higher education. The paper examines possible challenges posed in the context of South African Higher education. The paper then suggests a way forward to embrace artificial intelligence to enhance teaching and learning in South African Higher education, while at the same time ensuring equitable and lifelong learning.

Keywords: Artificial intelligence, higher education, intelligent tutoring systems, educational data mining, automated assessment

Introduction

Traditionally human beings derive algorithms that are then implemented on a computer to solve different problems. Artificial intelligence aims at building 'intelligence' into computer programmes to enable these programmes to learn and solve problems. The term artificial intelligence was coined by John McCarthy at a conference in 1956 (Russell & Norvig, 2003).

Initially the field of artificial intelligence focused on developing programmes for areas that represented human intelligence, for examples, winning at games such as chess or solving mathematical problems (Russell & Norvig, 2003). Hence, early artificial intelligence systems employed search algorithms to solve such problems. As the field developed, the area of expert systems, which mimics the way human experts solve problems, emanated. These systems also aimed at conversing with users in a natural language leading to the establishment of the area of natural language processing. The combination of artificial intelligence with robotics led to the development of humanoid robots that converse in a natural language (Silicano & Khatib, 2019).

One of the challenges with the earlier artificial intelligence techniques was that these approaches could not learn or adapt to the environment. This led to the field of machine learning (Alpaydin, 2010). Machine learning approaches aim to solve problems by learning from errors they make earlier in the process of solving a problem. Commonly used machine learning techniques include deep neural networks, random forests, support vector machines and logistic regression.

Artificial intelligence has contributed to various areas of higher education. Initiatives applying artificial intelligence to enhance teaching and learning began as early as the 1970's. The first attempt involved using artificial intelligence to provide individualized tutoring. The first system developed for this purpose was SCHOLAR (Guan, Mou & Jiang, 2020) which conversed with students in a natural language to tutor them in geography. This area later became known as intelligent tutoring systems (Nwana, 1990).

Intelligent tutoring systems focused research on developing techniques to assess student performance which in turn led to the field of educational data mining and learning analytics. These areas aimed to assess student performance to put in place interventions to ensure student success. Recent advances in artificial intelligence, such as deep learning, have contributed to the growth of both learning analytics and educational data mining.

As the field developed, the use of artificial intelligence for reducing the workload of educators in higher education was also investigated. This research resulted in the application of artificial intelligence to automate marking of various assessments such as essays. With the introduction of other emergent technologies such as virtual reality, visualization techniques, chatbots and augmented reality, artificial intelligence has been combined with these technologies to further enhance the teaching and learning experience.

This paper firstly examines the contributions that artificial intelligence has made in higher education internationally. The next section provides an overview of intelligent tutoring systems. An overview of artificial intelligence applied to learning analytics and educational data mining is then provided. The following section that examines the use of artificial intelligence for automated marking. The use of artificial intelligence to provide student support in terms of wellness and life skills is highlighted thereafter, followed by a section that examines potential changes to curricula and reskilling needed to apply artificial intelligence to different disciplines. Possible challenges in applying artificial intelligence in South African higher education are then discussed. The last section provides suggestions for the way forward to embrace artificial intelligence to enhance teaching and learning in South African higher education, while at the same time ensuring equitable and lifelong learning.

Intelligent Tutoring Systems

Intelligent tutoring systems (ITSs) are used to provide individualised tuition based on the particular student's needs (Chen, Chen & Lin, 2020) (Nwana, 1990) (UNESCO, 2018). While the effectiveness of individualised tutoring has been established, the challenges hindering the use of these tutors in higher education, includes finding sufficient tutors with the necessary skills as well as financial constraints for employing these tutors. This led to the development of ITSs. A further advantage of these systems is that students have access to them whenever they want to.

An intelligent tutoring system is comprised of the following modules (Nwana, 1990):

- Expert module – This module stores the content that the student is being tutored on. The content is used in tutoring the student as well as assessing student progress.
- Student module – This module keeps track of the student's knowledge of the different concepts and is used to diagnose errors and decide on what to present to the student next.
- Tutoring module - This module contains details of teaching strategies and pedagogic activities that can be used to tutor the content contained in the expert module.

- User interface module – Is used to interact with the students.

These four modules work together to interact with the student. Different artificial intelligence techniques are employed by each of these modules.

Intelligent tutoring systems have been employed for various disciplines including medicine, mathematics, computer science, physics, and various languages (Mousavinasab *et al*., 2021). To facilitate the use of intelligent tutoring systems and prevent reinventing the wheel authoring tools have been developed for the design and deployment of intelligent tutoring systems (Dermeval *et al*., 2018).

As other technologies emerge, these have been incorporated into ITSs to improve their capabilities. For example, chatbots have been used to communicate with students. Similarly, visualisation techniques and simulations have been used to illustrate concepts for certain disciplines. Image recognition algorithms are also being used to ascertain student responses from facial expressions.

Recent initiatives of artificial intelligence for tutoring includes the role of facilitator in online discussion groups (UNESCO, 2018) and online automated teaching assistants combining chatbots and intelligent tutoring systems. Jill Watson is an automated teaching assistant at Georgia Tech that answers student queries with a 97% accuracy.

Learning analytics and educational data mining

Learning analytics involves analysing data collected from learning management systems to predict student success or failure (Siemens & Baker, 2012) with the aim of putting in place interventions to overcome learning difficulties and assisting students achieve success. This has been done using either regression or classification. Regression for example models the student performance and predicts the mark that the student will obtain. Classification involves classifying the future performance of the student based on previous performance, for example pass, fail, complete in minimum time.

Learning analytics is a subarea of educational data mining which looks at predicting student performance on a larger scale (Baker & Yacef, 2009). This area has stemmed from intelligent tutoring systems where artificial intelligence was used to mine responses from students to identify learning difficulties and decide on which teaching strategy to use and content to present to the student at the particular point of tutoring.

Automated marking

Artificial intelligence has been contributing to reducing the workload of educationalists by automating the process of marking (Chen, Chen & Lin, 2020). In schools throughout China essays are being marked by artificial intelligence systems (UNESCO, 2018). Pearson has employed machine learning to assess various language proficiency tests that they offer online. It has been found that the artificial intelligence automated markers are just as accurate as educationalists, and in some instances achieve higher accuracy. Furthermore, automated marking was found to remove biases typical of human markers.

An area that has received a lot of attention is automated essay marking (UNESCO, 2018). Various machine learning approaches have proven to be effective for this (Madala *et al*., 2018). Automated marking has also been found to be effective for marking mathematics (Erickson *et al*., 2020) and computer programs (Ala-Mutka,2020).

Student support

In addition to contributing to teaching and learning, artificial intelligence has also made an impact in providing student support. Artificial intelligence student support systems have been used to assist students with:

- Student queries such as those on timetable, finance, technical problems.
- Advice, for example on admissions processes, which societies to join.
- Reminders, including of classes and deadlines.
- Monitoring and assessing performance.
- Wellness, for example detecting depression, providing mental health advice.

Different systems have been employed by different universities. For example, Pounce at Georgia Tech, Course-Q at Cornell University and Genie at Deakin University.

Curriculum and skills shift

The UNESCO report on artificial intelligence in education (UNESCO, 2018) indicates the need to relook at the content of curricula and instructional methodologies used at all levels of education, including higher education. The report also specifies that the main vehicle for developing artificial intelligence skills nationally are higher education institutions and research. Traditionally, artificial intelligence has been included in the curriculum for Computer Science degrees. However, given the current widespread use of artificial intelligence, artificial intelligence is relevant to various careers and hence various degrees. The challenge that faces higher education is how best to incorporate artificial intelligence into different curricula. It is important to remember that one size does not fit all. Different levels of understanding and knowledge is relevant to different curricula. For example, the curriculum for a Computer Science degree should cater for an in-depth knowledge and understanding of artificial concepts, whereas a curriculum for a law degree should include content on how artificial intelligence can be used in law, including the use of available tools such as decision support systems.

In order to successfully incorporate artificial intelligence into the different curricula it is important that educationalists in the different curricula are provided the support to upgrade their knowledge and skills to use artificial intelligence in their specific disciplines. Such support structures should be put in place by universities. Universities can also play a role in upskilling the workforce that has already graduated to use artificial intelligence in their careers. This can be in the form of career-specific short courses.

Challenges

The incorporation of artificial intelligence into higher education is not without challenges. Certain artificial intelligence algorithms, especially machine learning approaches, need high performance computing, such as GPU and multicore architectures, to run. Hence, the necessary infrastructure needs to be available in higher education institutions.

The widespread use of artificial intelligence is also hindered by the lack of availability of tools that can be used by non-experts to develop intelligent tutoring, automated marking and educational data mining systems. Research needs to be conducted by higher education institutions to develop such tools to bridge this gap.

The UNESCO report on artificial intelligence in education (UNESCO, 2018) highlights the need to provide equitable and inclusive education. A further challenge that artificial intelligence in higher education poses is facilitating equitable education for all. Policies and infrastructure need to be put in place to ensure the availability of artificial intelligence systems for teaching, learning and student support are available to all.

Conclusion

This paper has provided an overview of the applications of artificial intelligence in higher education. The expertise in artificial intelligence at higher education institutions needs to be harnessed to make this a reality for South African higher education. This will also require bringing together key stakeholders namely government, academia and industry. Artificial intelligence and its applications are a rapidly changing field and hence lifelong learning needs to be facilitated to keep up with the changes. Initiatives that have worked internationally include government support for research and training in artificial intelligence and national artificial intelligence labs, incubators, and centres of excellence. Hopefully the concept of the smart university (Usko *et al*., 2018) will become a reality in South Africa soon, as has the smart hotel with Hotel Sky.

References

Ala-Mutka, K.M. (2005). A Survey of Automated Assessment Approaches for Programming Assignments. *Computer Science Education*, 15(2): 83-102

Alpaydin, E. (2010). *Introduction to Machine Learning*. USA: MIT Press.

Baker, R.S., & Yacef, K. (2009). The State of Educational Data Mining in 2009: A Review and Future Visions. *JEDM-Journal of Educational Data Mining*, 1(1):3-17

Chen, L., Chen, P., & Lin, Z. (2020). Artificial Intelligence in Education: A Review. *IEEEAccess*, 8: 75264-75278

Dermeval, D., Paiva, R., Bitterncourt, I. I., Vassileva, J., & Borges, D. (2018). Authoring Tools for Designing Intelligent Tutoring Systems: A Systematic Review of Literature. *International Journal of Artificial Intelligence Education*, 28: 336-384

Erickson, J.A., Botelho, A.F., McAteer, S., Varatharaj, A., & Heffernan, N.T. (2020). The Automated Grading of Student Open Responses in Mathematics. In: *Proceedings of the Tenth International Conference on Learning Analytics and Knowledge*. Frankfurt: ACM: pp615-624

Goksel, N., & Bozkurt, A. (2019). Artificial Intelligence in Education: Current Insights and Future Perspectives. In: S. Sisman-Ugur, S. and G. Kurubacak, ed., *Handbook of Research on Learning in the Age of Transhumanism*, 1st ed., Hershey, PA: IGI Global: pp 224-236

Madala, D.S.V., Gangal, A., Krishna, S., Goyal, A., & Sureka, A. (2018). An Empirical Analysis of Machine Learning Models for Automated Essay Grading. *PeerJ* Preprints 6: e3518v1 https://doi.org/10.7287/peerj.preprints.3518v1

Mousavinasab, E., Zarifsanaiey, N., Kalhori, S.R.N., Rakshan, M., Keikha, L., & Saeedi, M.G. (2021). Intelligent Tutoring Systems: A Systematic Review of Characteristics, Applications and Evaluation Methods. *Interactive Learning Environment*, 29(1): 142-163.

Nwana, H.S. (1990). Intelligent Tutoring Systems. *Artificial Intelligence Review*, 4: 251-277.

Russell, S., & Norvig, P. (2003). *Artificial Intelligence: A Modern Approach*. England: Prentice-Hall.

Siemens, G., & Baker, R.S. (2012). Learning Analytics and Educational Data Mining: Towards Communication and Collaboration. In: *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*. Vancouver: ACM, pp. 252-254

Silicano, B. & Khatib, O. (2019). Humanoid Robotics: Historical Perspective, Overview and Scope. In: A. Goswami, P. Vadakkepat, ed., *Humanoid Robotics: A Reference*, 1st ed., Netherlands: Springer, pp. 3-7

United Nations Educational, Scientific and Cultural Organisation (UNESCO). (2019). *Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Developmen*t. France: UNESCO, pp. 1-46

Uskov, V.L., Bakken, J.P., Howlett, R.J., & Jain, L.C. (2018). *Smart Universities Concepts, Systems and Technologies*. Switzerland: Springer

The Implications of Fourth Industrial Revolution for Pedagogy in Higher Education in 21st Century South Africa

W. Kilfoil

University of Pretoria

wendy.kilfoil@up.ac.za

Abstract

The Fourth Industrial Revolution, powered by artificial intelligence and machine learning, is a topic of considerable interest in sciences, business, and education nationally and internationally. The problem from the point of view of this paper is, how might the Fourth Industrial Revolution, or its underlying technologies and their affordances, impact on higher education in the 21st Century, particularly in South Africa. This paper explores some insights from literature searches and conferences. The conclusion is that evidence of Fourth Industrial Revolution in education is scant but artificial intelligence and machine learning hold promise for higher education although they are not yet being used to any extent. Artificial Intelligence in Education (AIEd) has not been a focus of investments in the technology, but it has benefitted to some degree from advances made. Applying artificial intelligence effectively in any field requires inter-disciplinary collaboration between data engineers, data scientists and a diverse range of stakeholders and domain experts. Making decisions about changing the higher education curriculum to introduce artificial intelligence and machine learning into the curriculum as content will certainly require input from academics and students as will using AI as a delivery mechanism for the curriculum. Artificial intelligence has certainly made vast strides in the last few decades, but we are only at the beginning of its application, particularly in the field of education. Universities have time to make decisions about their artificial intelligence strategy, resourcing, and training of staff to promote its most effective use in higher education contexts.

Keywords: Fourth Industrial Revolution, pedagogy, inter-disciplinary, curriculum transformation, artificial intelligence, machine learning

Introduction and background

A buzz phrase in the second decade of the 21st Century has increasingly been 'the Fourth Industrial Revolution' or 'Industry 4.0.' The former will be used in this paper. The idea of a Fourth Industrial Revolution has grown out of the increased affordances of technology to some extent but even more out of research conducted into artificial intelligence (AI) and machine learning (ML) since the 1950s. Data engineers and scientists are actively researching the field, as is big business, often in collaboration with universities. However, little direct work has been undertaken for education, even by university engineering, computer science or information technology departments. Academics who are early adopters might have implemented some practical applications and experimented with basic artificial intelligence to improve student engagement but mainly there is much discussion and speculation. Universities will eventually be able to piggyback on business developments but they themselves rarely have the massive funding needed for research in the field for educational purposes.

The paper is structured as follows: the problem is stated as well as the exploratory review methodology to address the stated aim. The key terms 'pedagogy' and 'Fourth Industrial Revolution' are defined before a survey of some of the literature and unpublished research is discussed and analysed, including in the light of the South African higher education context. It does appear that curriculum transformation in terms of more inter-disciplinary studies and more artificial intelligence-augmented delivery are realistic scenarios for the future.

Statement of the issue addressed

The problem is, how the Fourth Industrial Revolution might affect higher education in the 21st century, particularly in South Africa. This paper explores some insights from literature searches and conferences. The conclusion is that artificial intelligence and machine learning as elements of the Fourth Industrial Revolution hold promise for higher education but are not yet being used to a significant extent as examples from South Africa and internationally show.

The issue is thus how universities can prepare themselves to take advantage of the affordances of the Fourth Industrial Revolution, such as artificial intelligence and machine learning, while maintaining the value and integrity of higher education, including the importance of human interactions in the development of curriculum, pedagogy and students (Johnson, 2016; Aoun, 2017; McGowan, 2019; Alaybeyi & den Hamer, 2020). Technology is almost ubiquitously used to enhance teaching and learning already so taking the process a step further into more advanced types of technology as they become available seems logical.

Aim and methodology

The aim of this paper is to explore and reflect on some of the emerging work in the field of Fourth Industrial Revolution and underlying technologies, and higher education. The focus is on how they might impact positively on South African higher education specifically.

No primary research was conducted for this article. The information comes from desktop research and conference and seminar attendance; that is, secondary sources. The purpose of the desktop research was to uncover existing knowledge about the Fourth Industrial Revolution and higher education and try to identify examples of use at various institutions and possibly some trends.

An online search revealed multiple research papers, reports, reviews and discussion papers on the Fourth Industrial Revolution and the use of artificial intelligence and machine learning in teaching and learning. Only a small proportion is referenced in this paper (Dodgson & Gann, 2017; Popenici & Kerr, 2017; Rowe, 2019; Schmulian &Coetzee, 2018). Most articles are recent and random, focused on individual experimentation with free or commercial technologies. Some quite extensive publications are also available based on reviews by large research teams or research institutions (Alaybeyi & den Hamer, 2020; Bughin *et al*., 2017; Luckin *et al*., 2016). Shorter press articles on developments in the field were also consulted (Aoun, 2017; Johnson, 2016; Riggs, 2018).

The desktop research was complemented by papers at conferences personally attended, hearing from leaders in artificial intelligence and higher education who have been doing ground-breaking work on the inclusion of artificial intelligence or machine learning to augment or enhance teaching and other fields (Cochrane, 2018; Marwala, 2019; McGowan, 2019). Papers at other conferences by similar experts were also sourced (Ludik, 2017; Miyagawa, 2019). In some cases, the websites of certain experts or

research entities were studied (Cochrane, 2018; Gartner, nd; McGowan, 2019).

Some internal organisational information was used to demonstrate practical applications of the concepts at the University of Pretoria to give examples of what is being done with technology already at a basic level of artificial intelligence, not incorporating machine learning (Schmulian & Coetzee, 2018). Free online tutorials written specifically for University of Pretoria students on the topic of artificial intelligence were reviewed (Matthee, 2019; Pillay, 2020). Discussions were also held with colleagues in Computer Science at University of Pretoria although they are not cited or referenced.

Literature review and situational analysis

What is pedagogy?

This paper uses 'pedagogy' to mean the delivery aspect of a curriculum, the content, and outcomes of which are determined by domain experts who might or might not eventually teach on the programme. This paper does not delineate any particular learning theory, so teaching is defined pragmatically as a designed activity aligned in terms of outcomes, material selection, student engagement and assessment as well as teacher presence (contact or virtual). It would seem that the Fourth Industrial Revolution might influence delivery and curriculum, but that curriculum design and content selection are still seen as human activities (Johnson, 2016; Aoun, 2017; McGowan, 2019; Alaybeyi & den Hamer, 2020). It is argued in some literature that, in preparing students for a future 'infused by artificial intelligence', universities need to alter the current curriculum and become more inter-disciplinary (Aoun, 2017). Active student engagement is key to student retention and success (Miyagawa, 2019) and it could be enhanced by technology, including the developing affordances of artificial intelligence. Assessment can also be more effective if technology is used optimally.

In recent years, one of the greatest areas of interest at universities has been the generation and analysis of data to improve student success. It is probably in this area that artificial intelligence plays the most prominent role currently, as machines are able to handle big data sets based on algorithms developed to extract the most from the analysis and make it predictive and actionable. Furthermore, such learning analytics affordances are often part of learning management systems, advantaging universities that have access to them.

What is the Fourth Industrial Revolution?

There are many definitions of Fourth Industrial Revolution, and it is clear that the phenomenon is related to the escalating affordances of technology, particularly in the field of artificial intelligence. The following attributes characterise the Fourth Industrial Revolution: (a) using data from multiple sources and applying algorithms (a defined set of steps for solving a problem) and machine learning (the ability of computers to learn from training and data instead of explicit programming): for example, for learning and learner analytics; and (b) cyber-physical systems.

One of the key points made by several experts is that human beings remain at the heart of the Fourth Industrial Revolution (Johnson, 2016; Aoun, 2017; McGowan, 2019; Alaybeyi & den Hamer, 2020). Even machine learning requires human decisions and training before a system can start to function more or less autonomously.

The discussion in this paper centres on practice rather than theory, the latter coming mainly from

the fields of computer science, data science, engineering, and information technology but also more broadly from physics. If one thinks of the various industrial revolutions, all were based on scientific developments and the fourth industrial revolution is no exception.

Delivering the keynote at the Department of Higher Education and Training Research Colloquium, Marwala (2019) referenced the underlying science briefly. The First Industrial Revolution, in the late 1700s, focused on mechanisation using steam and water, which Marwala attributed to the theories developed by Newton and Watt. The Second Industrial Revolution, in the late 1800s, brought in mass production powered by electricity and was based on the research of Faraday, Maxwell and Ørsted. The Third Industrial Revolution, in the latter half of the 1900s, was enabled by computerisation and the Internet, and influenced by the work on transistors based on semi-conductors by Bardeen, Brattain and Shockley, and it led to further automation. Ludik (2017:9) gives a similar outline of the successive industrial revolutions.

Each successive wave of industrial revolution took nearly a century to develop (Marwala 2019; Ludik, 2017). It is different for the Fourth Industrial Revolution, which 'started' in the early 21st Century, so there has been acceleration in the rate of change, which could be explained by the fact that research into artificial intelligence has been ongoing since the mid twentieth century and is now maturing. It is based on work on artificial intelligence by Turing, and subsequently many other scientists, and brings in cyber-physical systems, material learning and robotics. Ludik (2017:5) claims that Fourth Industrial Revolution

[b]uilds on the digital revolution and [is] characterised by the fusion of new technologies that are blurring the lines between the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human.

One caveat is that people should not become too obsessed with Fourth Industrial Revolution as there will no doubt be further 'revolutions' with time.

Many people conflate the greater use of technology with artificial intelligence and Fourth Industrial Revolution while it is very much a Third Industrial Revolution phenomenon. So, the following would be examples of the Third Industrial Revolution not the Fourth Industrial Revolution: (a) improved digital literacy of staff and students; better use of technology, for example, 100% of lecturers using a learning management system; and (c) the data in the Higher Education Management Information System (HEMIS) and dashboards and analyses based on those data.

The conflation of the large amount of data in HEMIS with big data is inaccurate as it is a repository for information from a limited number of universities on a limited number of fields and is collected once a year. It is also not immediately available for analysis. The research organisation, Gartner (nd), has three criteria for big data. These are high volume, high variety, high velocity.

Why artificial intelligence is more prominent than the Fourth Industrial Revolution in higher education

For the purposes of this paper, the Fourth Industrial Revolution as a process within higher education is not considered likely as currently it is neither planned for nor resourced. Artificial intelligence is far more likely to influence both the curriculum and educational processes as early adopters start to use its affordances. Machine learning as a sub-system of artificial intelligence also has the potential to

impact on higher education.

Pillay (2020), in a free online ready-for-work tutorial for all University of Pretoria students, 'Introduction to Artificial Intelligence', writes:

> Artificial intelligence aims to get computers to 'think' intelligently rather than follow an algorithm, [which is] a series of steps, derived by a human. Johan McCarthy coined the term artificial intelligence in 1956 at a conference held to discuss how computers could emulate computer intelligence. This phrase led to questions such as 'What is intelligence?' and 'Can computers think?'

Pillay (2020) shows in the tutorial that investigations into artificial intelligence actually started in the 1950s and went through highs and lows. It is only in the last decade that artificial intelligence has started to become more mainstream.

Alaybeyi and den Hamer (2020) define artificial intelligence as 'a series of mathematical or logic-based techniques to solve probabilistic problems' and machine learning as an artificial intelligence technique. Popenici and Kerr (2017:2) define artificial intelligence

> as computing systems that are able to engage in human-like processes such as learning, adapting, synthesizing, self-correction and use of data for complex processing tasks

and machine learning as

> a subfield of artificial intelligence that includes software able to recognize patterns, make predictions, and apply the newly discovered patterns to situations that were not included or covered by their initial design.

There are arguments from various sources that an understanding of artificial intelligence is more important than an understanding of any previous technology as it has the power to influence lives of people in ways that no other technology ever has (Miyagawa, 2019). Alaybeyi and den Hamer (2020) argue very strongly for transparency of artificial intelligence where its use can impact on decisions about human beings. One aspect of that transparency is having a diverse team of stakeholders and domain experts work with data scientists and engineers on the development of systems, including in higher education curriculum design and pedagogy.

The drive is to use artificial intelligence to solve real-world problems, including problems encountered in higher education, such as student success, personalised support for students, massification, large classes, shrinking budgets and so on. Academics themselves should be closely involved in creating clear descriptions of pedagogical problems and not leave this task to commercial companies:

The role of technology in higher learning is to enhance human thinking and to augment the educational process, not to reduce it to a set of procedures for content delivery, control, and assessment. With the rise of AI solutions, it is increasingly important for educational institutions to stay alert and see if the power of control over hidden algorithms that run them is not monopolised by tech-lords (Popenici & Kerr, 2017:4).

Students could also be involved in the process as their graduate attributes and future employability are affected by the curriculum and the pedagogical processes by which it is delivered.

Educational use of artificial intelligence and machine learning: So near and yet so far

The hype around the Fourth Industrial Revolution is raising possibly unrealistically high expectations. There is some implementation, but education in particular is far from starting to implement its potential. Artificial intelligence seems to be making greater inroads in education in reality. Cochrane (2018) estimated that 'almost 100% of all systems are on the very bottom rung of artificial intelligence evolution; almost entirely dumb, algorithmic, and only at the edge of intelligence'. A year later, Miyagawa (2019), talking about higher education, claimed that 'AIs are black boxes with algorithms' that you feed with data. So, there does not seem to have been much recent progress in the application of artificial intelligence and machine learning, let alone the Fourth Industrial Revolution in higher education.

Big companies plough billions into artificial intelligence to harvest even more billions (Bughin *et al*., 2017; Ludik, 2017; Popenici & Kerr, 2017). University research in the field often focuses on commercial markets like banking, rather than on educational applications. The motivation is return on investment rather than the public good, on which education focuses. Education is fortunate to be able to capitalise on advances but artificial intelligence in education it is not the goal of the original investment. Underlying artificial intelligence technology is being used by some companies with university clients, which brings about some exposure, but with algorithms embedded that are not necessarily transparent to the user, for example, learning management systems; publishers in their new e-guise, and so on.

One could speculate that behind closed classroom doors in higher education, there might be a mix of digital and artificial intelligence applications by early adopters: virtual reality, simulations, game-based learning, apps, homework programmes, 3D printing, data aggregators, YouTube, Facebook, and the like. Some academics are using creatively technology that is available free, for example, chatbots (FB messenger, Snatchchat, Google Dialogflow), Adobe Creative Cloud, and so on. However, it would be almost impossible to conduct an audit of such use to confirm that lecturers are using artificial intelligence-infused technology and the scope of that use. Certainly, recent attempts to identify artificial intelligence uses across faculties at University of Pretoria has led to the tentative conclusion that some exciting work is being done with technology to improve student engagement and learning, but perhaps only based on rudimentary artificial intelligence.

For instance, at the University of Pretoria, two innovative lecturers in the Department of Accounting Science implemented a chatbot as early as 2016 (Schmulian & Coetzee, 2018). It was based on Facebook Messenger and was virtual, with no physical robot necessary. It focused on frequently asked questions on their different modules. While it is easy enough to set up and keep up to date, it entails a great deal of lecturer time. Feedback shows that students think it is 'cool' because they can access it on their phones, consult it in class, and so forth. It is constantly available – they do not have to wait for consulting hours or class. It also provides reliable information – unlike 'ask a friend', usually students' first source of information. The lecturers have also held a training session at the University for colleagues interested in setting up chatbots.

A chatbot can also be a robot. The University of Pretoria library acquired a robot, which they named Libby (Department of Library Services, 2019). They were already collaborating on artificial intelligence research although Libby is not based on machine learning and has to be programmed. Libby provides customer service answers, does marketing and can be used to project a presentation. The developers used Google's Dialogflow for voice to text. It has open API for programming/ training, to add to questions and answers and to add to Library's knowledge base. It also integrates into the University

of Pretoria systems such as the UP App. The library conducts continual research into how staff and students interact with Libby. The Head of the Library, speaking at the launch of Libby (Moropa, 2019), described how some students kept their distance from the robot on first seeing 'her' and were startled when 'she' talked. Graduates should not be entering a workplace that might include robots and cyber-physical colleagues, and jumping in fright at the first encounter, so the robot provides valuable exposure to new technologies and adds to students' experience and graduate attributes.

Although these two examples might be on the 'bottom rung of artificial intelligence' (Cochrane, 2018) or what Popenici and Kerr term a 'low complexity artificial intelligence solution' (2017:5), they are a move in the right direction when it comes to graduate capabilities.

Koller, President of Coursera, claims that 'Robots Won't Replace Teachers because They Can't Inspire Us' (Johnson, 2016). She addresses issues such as the following, which rely uniquely on human capacity: (a) course design and development, including selection and sequencing of knowledge and skills, decisions on assessment, course resources, and many others; (b) content creation, (c) answering tough, complex questions; and (d) inspiration. 'People are social animals', Koller is cited in the article as saying. 'They like to learn in groups, and they like to learn from people.'

In the same year, Luckin *et al*. (2016) introduced the idea of Artificial Intelligence in Education (AIEd). Examples are the use of IBM Watson, for instance, at Georgia State University, and the Pearson e-tutor. IBM Watson is a technology platform that uses natural language processing and machine learning to reveal insights from large amounts of unstructured data.

Aoun (2017) writes about retooling higher education to defeat robots through a 'dramatic realignment':

> Instead of educating college students for jobs that are about to disappear under the rising tide of technology, 21st century universities should liberate them from outdated career models and give them ownership of their own futures. They should equip them with the literacies and skills they need to thrive in this new economy defined by technology, as well as continue providing them with access to the learning they need to face the challenges of life in a diverse, global environment.

This argument supports the need for curriculum change in higher education. Aoun acknowledges the fear of robots taking jobs – any predictable job, not just low-skilled. Yet he sees the Fourth Industrial Revolution as a boon for humanity. Riggs (2018) also comments on a paper read by Aoun at a conference in 2018:

> With up to half of white- and blue-collar jobs expected to vanish due to artificial intelligence (AI), the priority for universities is to make people 'robot proof' by teaching '*humanics*' – technical, data and human literacy – and providing experiential and lifelong learning.

The concept of 'humanics' seems to support the prospect of a more inter-disciplinary curriculum. In the presentation, Aoun emphasised the need for lifelong learning and 'stackable certificates', negotiated with employers, as well as experiential learning.

During his keynote at the Flexible Futures IV conference, Cochrane (2018) spoke on 'Artificial intelligence – Threat or Promise?'. Besides his extensive work on technologies in a variety of industries over decades, he has also contributed to university teaching. He discussed human ambivalence about artificial intelligence: as something to be welcomed *versus* something to be feared. He made it clear

that the technology in itself is neither good nor bad but that human beings might make decisions about its use that could result in 'dystopian futures'. He concluded that

> 'The truth is that, without artificial intelligence, almost all of human progress will come to a halt. We no longer hold all the abilities to unravel, analyse, and understand all the problems we face.'

He shared his own use of artificial intelligence to keep up to date with the thousands of publications in his field. His paper suggested that educational and work-based processes could be enhanced by artificial intelligence.

At the Times Higher Education (THE) Teaching Excellence Summit held in Canada, Miyagawa (2019), Senior Associate Dean for Open Learning, Massachusetts Institute of Technology (MIT), presented on 'What Skills Will Students Need in Order to Succeed in a Future Shaped by AI?.' He focused on two areas: (a) lifelong learning (using online resources/ digital literacy)'and (b) artificial intelligence literacy (particularly computational thinking).

Overall, Miyagawa is optimistic about the impact of artificial intelligence. He started with some statistics. He estimated that 14-47% of current jobs would disappear, to be replaced by artificial intelligence, the new Fourth Industrial Revolution workplace. However, 65% of university graduates would be working in jobs that do not exist today. He argued that that work would be more conceptually demanding and creative and that interpersonal skills would be at a premium. His argument suggests that not only does the curriculum have to change to include artificial intelligence but also to focus on uniquely human skills, creating a different set of graduate attributes.

In terms of continuous lifelong learning, he considered what educators could do to help students become lifelong learners. Students could be shown within their programmes that they have masses of structured and unstructured opportunities to learn from resources freely available online to keep up with rapid changes in technology and the need to reskill. He works at MIT and pointed out that their OpenCourseware platform, licenced under Creative Commons, has over 2,000 courses, and receives two million hits a month.

Miyagawa argued for active learning and gave two examples of how he has tried to make a MOOC in which he is involved more actively engaging for students, using artificial intelligence. He used discussion forums and their research revealed that the more students actively engage, the more likely they are to stay with the course. He set up an artificial intelligence tutor that could understand natural language and point students to a massive, annotated knowledge base and annotated short videos to answer their questions. That solution left time in the discussion forum for higher-level discussion. For this tool, he explained how much time it took to develop, as he did for his second innovation: grading essays on a massive scale. They deal with interpersonal skills and communication tasks in their MOOC. Miyagawa also explained that writing skills are much in demand by employers but even in contact teaching marking is an onerous task, never mind in a much larger MOOC class. He experimented in the MOOC with peer marking but the grades were all unrealistically high. He then started to use artificial intelligence and the marks had a much better spread and were more similar to those of a human marker. Whether for online or contact tuition, a reliable AI marking system would make life much easier. Artificial intelligence could thus be used to enhance teaching and learning, provide students with a reliable and all day and night resource, and relieve lecturers of onerous tasks.

In terms of artificial intelligence literacy, Miyagawa argued strongly that all graduates need some 'intuition' about artificial intelligence technology. He focused on computational thinking. He gave an example of how it is already taught in early childhood development courses (PopBots in Boston Public School system). Another example came from Finland, which is trying to get 1% of its population competent in computational thinking, in a participatory and democratic approach to artificial intelligence. Miyagawa's reasoning is that for the first time it is important for people to understand what is behind technology because artificial intelligence it has the potential to shape their personal and work lives in ways that a cell phone, for instance, does not.

One of the big concerns about artificial intelligence is that human biases are coded in, whether into facial recognition software or other systems. Miyagawa pointed out that we need to keep tweaking algorithms and data but that we shall never have perfect solutions because humans are not perfect. He also discussed ethics and risks involved in using artificial intelligence because human nature is not perfect. However, he concluded that artificial intelligence would contribute to an exciting future for education and that people are only limited by their imagination on what is possible.

Artificial intelligence tutors fall into the category described by Popenici and Kerr (2017:10) as 'teacherbots':

> At this point, we can see a teacherbot as a complex algorithmic interface able to use artificial intelligence for personalized education, able to provide bespoke content, supervision, and guidance for students and help for teachers. Teacherbots are defined as any machine-based software or hardware that assumes the role traditionally performed by a teacher assistant in organizing information and providing fast answers to a wide set of predictable questions; it can be facilitating, monitoring, assessing, and managing student learning within the online learning space.

The ideal is that, in the Fourth Industrial Revolution, technology will augment and enhance, not replace, teachers, with the purpose of addressing some of the problems facing higher education: growth in student numbers, staff: student ratios, large classes, and increasing administration (Popenici & Kerr, 2017). Not only that, but a teacherbot or what they also term a 'cloud-lecturer' (Popenici & Kerr, 2017) can help to provide more personalised learning for students, what Ludik terms 'personalisation at scale' (2017:107). They can perform the type of routine academic tasks that take up lecturers' time when they could be spending it more creatively. Dodgson and Gann (2017:2-3) give examples of work being done at Technical University of Berlin, Carnegie Mellon University, and the Georgia Institute of Technology.

Popenici and Kerr acknowledge that the practice of automating teaching could lead to abuse 'where teaching is replaced by artificial intelligence automated solutions' (2017:9). Somehow academics could lose control of both the curriculum and sound educational practices and education could become more instrumental and less about 'humanics.'

South Africans are also contributing to the debate, looking at both the advantages and threats of artificial intelligence and machine learning. For example, Rowe (2019), of the University of the Western Cape, makes the following points:

- Artificial intelligence and machine learning are not neutral: the software is influenced by the choice and quality of data and who trains the software.

- How do designers know what students and teachers need in classrooms?
- How does the software support a constructivist approach to teaching and learning and the social justice agenda?
- It is essential to have students and teachers collaborating in the design, development, training and piloting of software.
- 'The introduction of artificial intelligence into various aspects of teaching and learning is inevitable and the more we rely on algorithms to make decisions, the more they will shape what is seen, read, discussed, and learnt.'
- 'The introduction of artificial intelligence into education is not a technological problem; it is a human and social problem.'

In stressing the role of students and teachers in developing artificial intelligence systems, Rowe is in line with Gartner's most recent recommendations for the inclusion of diverse stakeholder groups to work with artificial intelligence scientists in the design of workable solutions to real-world problems (Alaybeyi & den Hamer, 2020).

Ludik is also based in South Africa and focuses on African uses of artificial intelligence in all fields. Ludik (2017) classifies education generally as having low artificial intelligence adoption and low digital maturity. He ascribes this undesirable situation to '[t]he current absence of sophisticated use of artificial intelligence technologies in schools, colleges, and universities may be explained by the lack of financial resources as well as the lack of data establishing the technologies' effectiveness' (Ludik, 2017:107). The situation makes it less likely that the Fourth Industrial Revolution will have a short-term impact on higher education.

He devotes a large section of his presentation (Ludik, 2017) to African contexts: health, agriculture, SKA telescopes, and even education. One slide in his presentation focuses on 'Smart technology empowered education-entrepreneurship ecosystem to transform Africa' (Ludik, 2017:53) and another on an ERA online platform for student learning. He has a vision of a whole Fourth Industrial Revolution 'Education-Entrepreneurship Ecosystem' (Ludik, 2017:74). The caution that he raises is that the Fourth Industrial Revolution could lead to increased prosperity for all or widen existing inequalities.

Ludik lays out a number of strategies for South Africa and universities are central to the ecosystem he envisages (2017:93). His ideas on the key role of universities are supported by other people working in the field, for instance:

> Universities will need to be attuned to the new opportunities AI produces for supporting multi-disciplinarity. In research this will require creating new academic departments and jobs, with particular demands for data scientists. Curricula will need to be responsive, educating the scientists and technologists who are creating and using AI, and preparing students in fields as diverse as medicine, accounting, law and architecture, whose future work and careers will depend on how successfully they ally their skills with the capabilities of machines (Dodgson & Gann, 2017:5).

Despite the focus on artificial intelligence and machine learning and their implications for the workplace, most experts believe that human value will remain. However, people need to be flexible, and need to be life-long learners. McGowan (2019), in her keynote at the Flexible Futures IV conference at the University of Pretoria, on 'The Future of Work is Learning', made several telling points. She maintained

that in the past people learnt to gain employment; in future, they will learn at work and keep unlearning and relearning. They will have to learn and adapt to create new value in an environment increasingly moving towards artificial intelligence. There will be continuous change in occupational identity and multiple careers. A student cannot learn what he or she will need know in the course of a short period at university. She pointed out that the fastest growing skills needed in the workplace change regularly. The future of work is not only about technology but about leveraging the uniquely human skills that people have, such as high social skills. Her advice was to develop a resilient and adaptive personality; an agile mindset to learn and adapt, and uniquely human soft skills. She recommended that students should determine what interests them, what drives them, what gets them excited and then what their unique abilities are and apply their gifts to their purpose.

Analysis and Discussion of Information Acquired

Curriculum Transformation

Decisions about curriculum, as pointed out by Koller (Johnson, 2016), are within the human domain at the moment. In terms of artificial intelligence and preparing students to work and live in the era of the Fourth Industrial Revolution, curriculum transformation means introducing higher education qualifications in the field of artificial intelligence and machine learning, or inter-disciplinary programmes that incorporate artificial intelligence and machine learning into the curriculum. To expand on the idea of 'humanics' introduced earlier, different types of literacy would have to be included in a newly conceptualised curriculum:

> technical literacy, as everyone has to understand how to work with tech and robots; data literacy, to help interpret 'the sea of data' that is now available; and human literacy, which includes identifying what we can do that machine can't do, such as innovate, understand body language, work in teams and 'be globally and culturally agile (Aoun, 2017).

The literature review and conference attendance leave one with more questions than answers. Will institutions focus on artificial intelligence higher education qualifications such as degrees in computer science programmes or on inter-disciplinary degrees infused with 'humanics'? Or both? How can current lecturers, who know their disciplines only, be expected to teach artificial intelligence? How can discipline experts be persuaded to think in an inter-disciplinary way? They are employed for their specialist knowledge and continually rewarded for research in their disciplines. How can the knowledge base that students need be established? Their curriculum is already crowded, so how possible is it to introduce technical and data literacy for humanities-type qualifications and human literacy for more science-based higher education qualifications such as degrees? It is obvious that there would have to be different scenarios for different contexts. It would be better if decisions about these scenarios were planned and strategic, rather that *ad hoc*.

Who at the university will lead, drive, inspire, and provide the expertise in artificial intelligence for education? Few universities have the advantage of someone with forty years of hands-on management, technology, and operational experience like Cochrane (2018), who was appointed as the first Professor for the Public Understanding of Science and Technology at the University of Bristol in 1998 and in 2018 as Professor of Sentient Systems at the University of Suffolk.

To raise awareness about the importance of artificial intelligence for everyone's future, develop an intuition about artificial intelligence (Miyagawa, 2019), and create more inter-disciplinary competence

in the teaching staff at universities, there are a number of options, of which the following are just a few:

- Expose all lecturers to a course on computational thinking.
- Pilot the design of inter-disciplinary degrees to include, for instance, political science, basic data science and basic technology knowledge, each lecturer focusing on his/ her own competence. Team teaching could be an option for inter-disciplinary programmes as well.
- Guide lecturers through professional development programmes on how to incorporate easy-to-use software into student activities: apps, games, google drive, podcasting, and so forth.

An alternative, and a space for a quick win, is to use a non-formal mechanism to introduce students to artificial intelligence. Innovation often takes place at the periphery of the education system, in short learning programmes, that are quicker to produce and do not need to follow an external process of approval by statutory bodies. Such an example is the University of Pretoria's ready-for-work programme, run by Enterprises UP in collaboration with the Career Services office. Pillay's (2020) professional online development (POD) tutorial on artificial intelligence was discussed earlier. It is a generic introduction to artificial intelligence and will be complemented by other PODs, one per faculty, showing how artificial intelligence is already affecting specific fields in different ways. However, just thinking about the range of disciplines and professional degrees in each faculty, even this will not be enough to give students a specific idea of how artificial intelligence and the Fourth Industrial Revolution are affecting their chosen careers. Programmes requiring work-integrated-learning (WIL) (most engineering programmes), or clinical practice (most health sciences degrees) give students the best opportunity of seeing how technology is being used in the contemporary workplace. For students uncertain about a career, who are studying a generic degree, internships, job shadowing, simulations, game-based learning, experts from various fields addressing students, career fairs, and the like, could contribute to raising awareness about how the Fourth Industrial Revolution is affecting the workplace. A university can never prepare a student 100% for the workplace: indeed, that is not its function. Graduates will learn in the workplace (McGowan 2019) and become lifelong learners, one of the attributes identified by Miyagawa (2019) as key.

Another POD offered to the University of Pretoria students is thus 'Learn Unlearn Relearn – Lifelong Learning for the Fourth Industrial Revolution'. The purpose statement reads:

> This tutorial focuses on the realities of working in an increasingly digital world where machine learning and robotics will enable software, and sometimes hardware like robots, to take over both routine manual and cognitive tasks as well as make potentially life-altering decisions based on big data and algorithms.
>
> ...
>
> Your degree might have prepared you for only one of these literacies so you will need to take every opportunity to strengthen your knowledge and skills in the other areas to thrive in the digital economy. You will have to be prepared to be a lifelong learner as technology growth is exponential. Yet, as humans, we need not be victims to technological determinism even if the digital revolution is inevitable. (Kilfoil, 2019)

Miyagawa (2019) in particular argued for students to develop an 'intuition' for artificial intelligence. The ready-for-work POD tutorials are divided into packages and the University of Pretoria has placed in the very first package the POD 'Computational Thinking for Problem Solving':

The purpose of this tutorial is to provide a basic introduction to computational thinking, a skill that underlies an understanding of using logic to solve problems in non-computing environments in everyday life and the workplace as well as on computers (Matthee, 2019).

In the South African context, there are challenges such as the infrastructure in rural areas, particularly access to devices and the internet, even for universities. General resourcing of universities is also an issue. Students will often enter a working environment where the technology is newer than that which they used during their studies and where investigation of the application of new technologies is likely to be more intense in order to give a business a competitive edge.

Role of statutory bodies

If it is accepted that new, inter-disciplinary degrees will need to be developed, universities need to start work now, if they have not done so already. Designing a new university programme might take up to eighteen months within the university before Senate approval. Then it can take an equal amount of time for the approval, accreditation, and registration of the programme by various statutory bodies. The process is neither flexible nor agile.

In South Africa, the role of statutory bodies such as the Department of Higher Education and Training (DHET) and the Council on Higher Education (CHE) in the introduction of inter-disciplinary programmes needs to be considered. They respectively approve new programmes for funding on the programme and qualifications mix (PQM) and accredit new programmes.

Will the DHET approve inter-disciplinary programmes focused on preparing students for the Fourth Industrial Revolution on the PQM? They use a restrictive Classification of Educational Subject Matter (CESM) that determines funding categories, among other things. Universities are required to indicate the CESM category for any qualification. Will the CHE accredit inter-disciplinary qualifications? The CESM is also part of their application form. Evaluators for accreditation are subject-matter experts. These could be limiting factors when it comes to the approval of innovative qualifications.

Findings

It is not yet clear what impact the Fourth Industrial Revolution will have on the nature of higher education qualifications and processes. At most, there are examples of how some of the technologies underlying the Fourth Industrial Revolution, artificial intelligence/ machine learning, are being explored for teaching, learning, assessment and student support and development. As can be seen from the literature reviewed in the previous section, artificial intelligence can already support teaching and learning through robotics or virtually, for example, chatbots can supply content on handheld devices, even in blended learning environments; analytics can identify patterns in individual or class data for prediction or immediate action; reading programmes can evaluate a student's reading level and place her/ him appropriately in the programme; aggregation of data from online courses is possible; e-tutoring, e-mentoring, e-advising are all in operation but have yet to be scaled; reliable assessment using a rubric is already being practised in contact and online education; and, there are some computer programmes that can proctor remote examinations to prevent cheating.

However, there is little evidence of education systems or institutions adopting a systematic approach. Given that there is such investment in the Fourth Industrial Revolution in many of the professions into which graduates are moving, they are likely to encounter the challenges and affordances once

they leave university. Graduate attributes would need to change, which would mean changes to the curriculum or even the programme and qualification mix.

Conclusions and proposals

What people hear, read and experience on 'artificial intelligence and the workplace' or 'artificial intelligence for higher education' suggest a number of activities that could underpin the more effective use of artificial intelligence and machine learning for student success in the emerging Fourth Industrial Revolution environment. The following are some ideas.

At a leadership, strategic and policy level, universities need to develop an artificial intelligence/ machine learning strategy for their business operations as well as for teaching and research and possibly amend core policies as a result to develop a mindset that embraces technology. If the artificial intelligence/ machine learning strategy is embedded in the institution's overall Strategic Plan, it has more chance of implementation, resourcing, monitoring and evaluation. On the operational side, the strategy should encompass both financial and human resource allocations.

Training and development should form part of the strategy. Learning about (and with) technology is an important way to equip staff and students with the skills necessary to work in an artificial intelligence-infused environment. The interventions should include improving the digital literacy of staff and students; that is, their ability to use digital tools to communicate, solve problems, be creative; designing and offering short courses to bring all students and staff up to speed on computational thinking; designing and offering short courses on artificial intelligence/ machine learning for staff and students; and designing and offering continuous professional learning opportunities for academics focusing on how to incorporate artificial intelligence/ machine learning technologies into pedagogy.

The strategy should encourage experimentation (including through incentives and rewards) and creative risk-taking.

Some new inter-disciplinary qualifications could be designed and piloted. A seed fund for such experimentation could be made available and would include funding for the necessary technology.

The institution could require some computer science and engineering research into higher education by their academic artificial intelligence/ machine learning staff, working in collaboration with academics, students, and student support departments.

Partnerships should be prominent in the strategy. Business is investing massively in artificial intelligence/ machine learning. The university can collaborate with providers that are using artificial intelligence/ machine learning to influence design, training, algorithms, analytics, and related matters. Another valuable set of partnerships would be with employers who are using artificial intelligence/ machine learning to organize work experience opportunities for students on a work-to-learn principle.

Considering everything, it is obvious that artificial intelligence/ machine learning already has a significant influence on all aspects of life, including education. Their development is still limited, and the Fourth Industrial Revolution is best described as emergent, with development uneven across different sectors. Therefore, institutions have time to determine an adoption strategy and resource it adequately, to prepare themselves for the emerging Fourth Industrial Revolution, in their programmes and processes, to ensure that graduate attributes begin to match the future (and in some cases present) demands of the Fourth Industrial Revolution in the workplace.

References

Aoun, J.E. (2017). Robot Proof: Higher Education in the Age of Artificial Intelligence. (excerpt). *Daily Beast*. MIT Press. Available at: https://www.thedailybeast.com/we-need-to-retool-higher-ed-to-defeat-robots

Alaybeyi, S., & den Hamer, P. (2020). *Debunking Myths and Misconceptions about Artificial Intelligence*. Gartner

Bughin, J., Hazan, E., Ramaswamy, S., Chui, M., Allas, T., Dahlström, P., Henke, N., & Trench, M. (2017). *Artificial Intelligence: The Next Digital Frontier?* Discussion Paper. McKinsey Global Institute. Available at: https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/our%20insights/how%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/mgi-artificial-intelligence-discussion-paper.ashx

Cochrane, P. (2018). 'AI – Threat or Promise?' Keynote given at Flexible Futures IV, *Technology-enhanced Teaching, Assessment, Learning and Student Success*. University of Pretoria. (https://it-online.co.za/2018/11/06/artificial-intelligence-threat-or-saviour)

Department of Library Services. (2019*). Libby: UP Library's first service robot*. University of Pretoria. Available at: https://www.youtube.com/watch?v=8FXfIRJ77bQ

Dodgson, M., & Gann, D. (2017). Artificial Intelligence Will Transform Universities. Here's how. *World Economic Forum*. Available at:

https://www.weforum.org/agenda/2017/08/artificial-intelligence-will-transform-universities-here-s-how/.

Gartner. (nd). *Gartner Glossary*. Available at: https://www.gartner.com/en/information-technology/glossary/big-data.

Kilfoil, W. (2019). *Learn Unlearn Relearn – Lifelong Learning for the 4th Industrial Revolution*. Professional Online Development tutorial, University of Pretoria

Johnson, E. (2016). Robots Won't Replace Teachers because They Can't Inspire Us. *Recode*. Available at: https://www.recode.net/2016/6/22/11985726/robot-teachers-artificial-intelligence-coursera-daphne-koller

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence Unleashed. An Argument for AI in Education*. London: Pearson. Available at: https://www.pearson.com/corporate/about-pearson/innovation/smarter-digital-tools/intelligence-unleashed.html

Ludik, J. (2017). Artificial Intelligence: Impact & Applications, Skills & Employment, Current & Future Scenarios. PowerPoint presentation for Accelerate Cape Town. Available at: http://acceleratecapetown.co.za/wp/wp-content/uploads/2017/11/Artificial_Intelligence_-_Dr_Jacques_Ludick_MIIA.pdf.

Marwala, T. (2019). Fourth Industrial Revolution. Keynote at the Department of Higher Education and Training Research Colloquium, *The Fourth Industrial Revolution: Implications for Post-School Education and Training*, Kempton Park

Matthee, M. (2019). *Computational Thinking for Problem Solving*. Professional Online Development tutorial, University of Pretoria

McGowan, H. (2019). The Future of Work Is Learning. Keynote at *Flexible Futures V Conference*, University of Pretoria. www.work-to-learn.com

Miyagawa, S. (2019). What Skills Will Students Need in Order to Succeed in a Future Shaped by AI? *THE Teaching Excellence Summit, Degrees of Change: Forces Shaping the Teaching and Learning of Tomorrow*. Western University, Canada. Available at: https://event.worktimetv.com/teaching-excellence-summit-2019.

Moropa, R. (2019). Opening at launch of Libby. Department of Library Services. University of Pretoria

Pillay, N. (2020). *Introduction to Artificial Intelligence*. Professional Online Development tutorial, University of Pretoria

Popenici, S.A.D., & Kerr, S. (2017). Exploring the Impact of Artificial Intelligence on Teaching and Learning in Higher Education. *Research and Practice in Technology Enhanced Learning*, 12:22. DOI 10.1186/s41039-017-0062-8 Springer Open

Riggs, P. (2018). In the AI Era, Universities Must Make Us 'Robot Proof' – Implications for the Curriculum. *World University News*. Available at: http://www.universityworldnews.com/article.php?story=20181009085732640

Rowe, M. (2019). Shaping Our Algorithms before They Shape Us. Available at: https://www.researchgate.net/publication/333767314

Schmulian, A., & Coetzee, S.A. (2018). The Development of Messenger Bots for Teaching and Learning and Accounting Students' Experience of the Use thereof. *British Journal of Educational Technology.* Doi:10.1111/bjet.12723

The Fourth Industrial Revolution in Higher Education in South Africa: A Case for Blockchain Adoption

C. N. M. Ouma*, N. A. Odhiambo**, A. Kadyamatimba***, & N. M. Ochara***

** HySA Infrastructure, North-West University*

***Data to Information, Pretoria*

**** Department of Business Information Systems, University of Venda*

Corresponding author: moro.ouma@nwu.ac.za

Abstract

Blockchain technology is one among the technologies that drive the Fourth Industrial Revolution. The disruptions blockchain technology has caused to sectors such as finance should serve as a warning to higher education institutions that they cannot continue operating in a business-as-usual fashion. The higher education institutions should chart the way for the rest of the society in embracing and adopting the Fourth Industrial Revolution and technologies driving it, such as blockchain. Blockchain can serve as an immutable ledger, that allows the functions of higher education systems (including student record administration, course content, accreditation, credentials among others) to take place in a decentralised manner.

Keywords: Fourth Industrial Revolution, higher education, blockchain, credentials, ledger

Introduction

The Fourth Industrial Revolution is the talk of the town. Many institutions and governments are either embracing or grappling with the extent to which they can embrace or adopt it. This is because of the consternations resulting from the disruptions that have become synonymous with the Fourth Industrial Revolution. Critical sectors of the society can attest to these disruptions with the financial sector, as always, receiving the short end of the stick. While there is scant concurrence on the definition of the Fourth Industrial Revolution, there is some level of consensus on the key technologies that are fuelling it. These include improved computation power and quantum computing, block chain, artificial intelligence, advanced materials, 3D printing, and 5G technologies, among others. There is therefore need to build and nurture competencies that will match, exploit, and utilise these technologies, hence the space for higher education (Haugsbakken & Langseth, 2019). This is because, the workforce of the future will need to be armed with diverse skillsets suited to these technologies. The World Economic Forum posits that 65% of children entering primary school today will end up working in completely new jobs that don't exist yet. This calls for agility within the higher education sector if these children are to be suited for the Fourth Industrial Revolution jobs (Awaji, Solaiman & Albshri, 2020; Haugsbakken & Langseth, 2019; Palanivel, 2019; Tapscott & Tapscott, 2017).

For South Africa to adopt the Fourth Industrial Revolution there is need for higher education institutions to adequately prepare students with the right skills that will enable them to come up with fresh and innovative solutions to problems society is facing today and tomorrow. The government and

institutions of higher education ought to acknowledge that a characteristic of this revolution is how harshly it enslaves those who rebel against it. If not embraced with the proper skillsets, it can lead to great inequalities within the society. The democratisation of the Internet (Alam & Benaida, 2020) has turned the world into a global village and thus, the ripple effect of inequalities stemming for the failure to equip citizens with the right skills for the revolution will lead to other countries being generators or manufactures of technologies and innovation with South Africans just being consumers. Therefore, in order to address these inequalities, higher education institutions have the enormous task of embracing and adopting the Fourth Industrial Revolution.

Among the key drivers of the Fourth Industrial Revolution is the blockchain technology. Blockchain has attracted plaudits and sceptics in equal measure as a result of its disruption in the financial sector, thanks to cryptocurrencies such as Bitcoin, Ethereum and others. It is described as a distributed or decentralised immutable ledger system in which each ledger entry is a block that is time-stamped, encrypted and replicated at all of the parties (nodes) along the chain (Awaji, Solaiman & Albshri, 2020). A tenet of blockchain is its elimination of the need for trusted third parties in a transaction. Trusted third parties in transaction exist only when there is a central authority tasked to oversee, monitor, and adjudicate transactions. Key weakness of a centralised system (a system with central authority) includes lack of trust, insecurity, cost, and it can also be the single point or source of failure. Hence, decentralisation when it comes to transaction data exchange and storage is what blockchain aims for (Haugsbakken & Langseth, 2019; Tapscott & Tapscott, 2017).

The social-material nature of the society (Ochara & Odhiambo, 2018) coupled with information democratisation as delivered online via social media platforms, is making the Internet to be more or less a canvas upon which blockchain applications and technologies can be drawn and displayed. The Internet has value stemming from all the data and information exchanged by the users. Thus, with the rise of and the need for a distributed, trusted, transparent and secure peer-to-peer platforms, there is need to reengineer structures within institutions of higher education for innovation and value creation or co-creation.

The *status quo* of higher education institutions is characterised by institutional bureaucracies and vertical hierarchies analogous to the archaic industrial age. So, have higher education institutions in South Africa embraced or adopted the Fourth Industrial Revolution technologies such as blockchain? It is incumbent for them to start because these technologies are already reinventing the financial sector and soon other sectors will be reinvented as well including higher education.

Higher education institutions can leverage some of the unique features of blockchain such as immutability (stored data/information is tamper-proof), provenance (easy to track the origin of data/information), decentralisation (data/information not stored on a central system (server), and trust (no third parties involved) to create a trusted, secure, and transparent network of educators and students. Thanks to the Internet of Things (IoT), there are billions of smart devices ranging from portable devices (for example, cell phones, tablets) to wearable devices (for example, smart watches) that sense, respond, communicate, and share important data among other things that can be exploited by these higher education institutions for innovation and value creation or co-creation. This is because already, a trusted, transparent, and secure ledger-system is needed to capture and store the data and information shared, stored, and transmitted by these smart devices.

The *status quo* of higher education in South Africa

Higher education institutions in South Africa have the ultimate aim of providing education to their students, where education entails the transfer of knowledge across generations, past and present, in a truthful and reliable manner. The transfer of knowledge in this case elicits much trust in authorities as vested in agents or entities within the institutions. It is these agents or entities who wield the power to admit students, keep student records, decide on the curriculum, decide on who passes and fails, decides on how much to pay and the form of payment, hire and fire educators, award diplomas, degrees, and certificates, among others. Within such a system, the records will have a central point of storage and access to these records is often laborious due to the institutionalised bureaucracies. In these institutions, the student can only learn what is offered by the institutions and admissions may take place based on criteria established by the intuitions' governance structures. A national imperative for higher education institutions in South Africa is transformation (Mzangwa, 2018; Mzangwa & Dede 2019; Steyn, 2000) which refers to the removal of inequalities and the move towards equal education, shifting away from a monocultural educational system, migrating from content-based education to outcomes-based education, democratisation of education, and improvement of the quality of education (Steyn, 2000).

Scholars and the government concur on some of the interventions needed to achieve transformation in higher institutions. These can loosely be reduced to achieving equity and quality in education. The goal of transformation in higher education in South Africa greatly pivots on United Nation's Sustainable Development Goal 4 of ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all (McGreal, 2021). In formulating this goal, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) estimated that by 2025, over 100 million learners will have the capacity to pursue higher education but will not be able to access it due to either the courses not being affordable, or the courses not being offered where they reside or near to where they reside. The lack of courses in some regions, countries or locations can be attributed mainly to the lack of technological infrastructure, suitable content, internet connectivity or enough qualified instructors on the courses.

Currently, many higher education institutions engage in distant learning programmes, online learning, and blended classroom learning, among others. However, these measures to achieving the UN's Sustainable Development Goal 4 are still plagued by cost challenges, infrastructure challenges and shortage of qualified personnel. Additionally, online certifications usually do not engender the same level of trust and esteem as those the conventional contact higher education systems. In some instances, different institutions will have different requirements to pursue a higher education programme. Thus, qualifications obtained in one country, location, school, university, or region may not be valid in another, notwithstanding the cost incurred in pursuit of the qualifications.

All this calls for a distributed, transparent, and trusted ledger-based system that will level the playing field for all students and educators. Blockchain-like technology enables such system to be created and operated. It provides means for ascertaining provenance (a record-keeping platform), ensuring transparency (participants in the chain can download and validate individual records (ledgers)) and permanence (immutable). As it applies to education, blockchain aims to transfer value that is intrinsic to the content and not just the content itself.

Opportunities for blockchain technologies in higher education in South Africa

In the wake of the Covid-19 pandemic, higher education institutions both in South Africa and the rest of the world were compelled to abruptly pivot to online solutions (McGreal, 2021) for teaching and learning, meetings and graduations in addition to (re)examining their strategies with regards to the same. This was marred by a myriad of challenges stemming of the institutions' unpreparedness for such interventions. However, they still had to find ways to continue operating there were nationwide lockdowns and closures of institutions. They still had to complete their curricula, administer examinations, hold graduation ceremonies, and deliver diplomas and certificates to graduates safely and securely. The cost sending hard copies of certificates to the graduates was relatively high because institutions had to enlist trusted courier companies such as DHL to deliver them to intended recipients. All these attests to the need for a form of paradigm shift in the *modus operandi* of higher education institutions in South Africa. A plethora of opportunities abound when it comes to technological innovations in higher education (*Figure 1: An example of blockchain system of how higher education institutions*).

There opportunities to improve the operations of higher education institutions such as student identification and student records and pedagogy (Haugsbakken & Langseth, 2019; Moore, 2019; Schroeder, 2020). The blockchain technology within the Fourth Industrial Revolution can help navigate through the paradigm shift needed in higher education systems in South Africa and beyond.

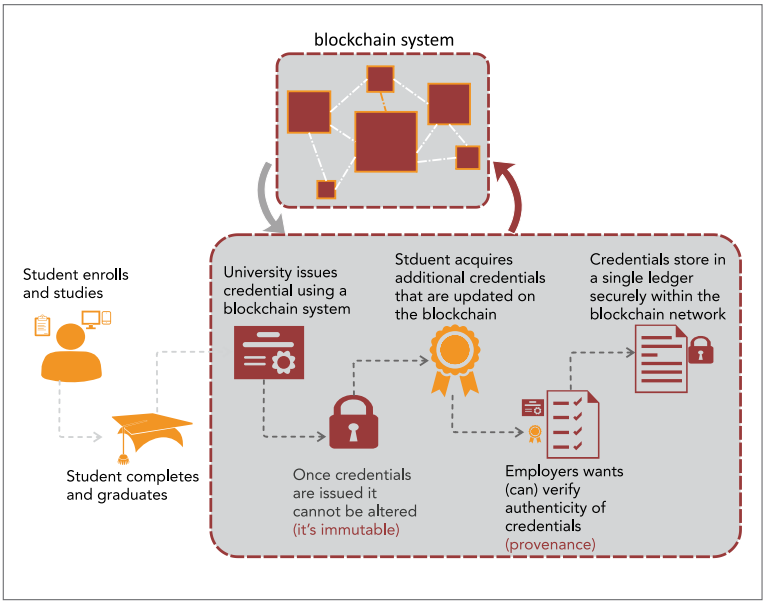

Figure 1: An example of blockchain system of how higher education institutions

Vest's dream philosophy of the future of higher education

Vest (2006) posed the following questions with regards to the future of higher education.

- What is the appropriate use of "educational technology" in teaching, learning, and scholarship?
- What will be the nature of globalization of higher education?
- Will the Internet fundamentally reshape higher education?
- Are residential colleges and universities dinosaurs or the wave of the future?

In these questions, Vest (2006) correctly envisioned what dominates the hyped digital revolution in higher education today. Where entrepreneurs invade the higher education space and hijack the learning process by either being the creators of the content through hiring educators and recording their content for sale or them assuming the role of higher education institutions themselves. Vest (2006) decried how an attack on the mandate of higher education systems can be an affront to the tenets of higher education. To this end, institutions such as the Massachusetts Institute of Technology (MIT) school of engineering engineered an education revolution where 'subjects were redeveloped on a base of science, and new teaching materials were generated throughout MIT—lecture notes, problem sets, and experiments. In due course much of this was formalized as published textbooks and textbook series. But what really propagated the "engineering science revolution" was that many of the rapidly increasing numbers of engineering PhD's educated at MIT joined faculties of universities and colleges all across the country, bringing with them their lecture notes, draft textbooks, problem sets, and laboratory experiments. These faculty moving throughout the country adapted their teaching materials to their new environments. They added to, subtracted from, and used the materials to teach at varying paces. This merged into developing programs in many colleges and universities, and before long, the nature and quality of engineering education was elevated across the country' (Vest, 2006).

In this instance, the philosophy at MIT imparted trust on how the same engineering science education ought to be delivered to the students in different locations. Additionally, in light of the above, there was need to track how this education is delivered, who is delivering the information, who is it delivered to and how is the recipient utilizing it. The lectures and teaching materials (including PowerPoint presentation and lecture notes) used can be delivered online using mediums such as online courses in virtual classrooms using opensource online repositories (Sangai, 2018). Students can use them in web-based laboratories where thanks to the power of the Internet, experiments can be controlled from any distance in virtual laboratory. It is this open access architectures (in virtual classrooms and laboratories) that have led to the emergence of what is referred to as a 'meta-university' (a transcendent, accessible, empowering, dynamic, communally constructed framework of open materials and platforms on which much of higher education worldwide can be constructed or enhanced).

This meta-university movement has led in part to, open science, open access publications, open universities and to some extent online courses. All of which need a trusted ledger-like system that is decentralized, immutable, and has provenance.

Notwithstanding the mushrooming of decentralised (digital) learning platforms and opportunities, there was still no way of digitally tracking and managing accomplishments, credentials, instructors/ educators, and students. An attempt to digital tracking of academic credentials has been made by 'Blockcerts', an open-source toolkit developed by MIT school of engineering to be used to offer credentials using blockchain. Since its launch, several higher education institutions have leveraged blockchain related technologies towards offering secure credentials.

The advantages of deploying blockchain technology (*Figure 1: An example of blockchain system of how higher education institutions*) in such a higher education system include but not limited to credentials

being digitally secure and tamper proof; students having the power to access, download their earned credentials, instantly sharing them when and where they choose; digital badges being able to provide a model starting point for integrating entries into the blockchain; details being stored on the ledger by the institution, so entries are more than a course name and number -- they can include topics mastered and even examples of work; credentials being expandable to non-credit bearing activities and accomplishments, such as internships; courses being standardised; and instructors and their credentials being clearly identified (Alam & Benaida, 2020; Awaji, Solaiman & Albshri, 2020; Tapscott &Tapscott, 2017).

Identity and Student Records vs blockchain

Identity or identification is of importance to any individual (Haugsbakken & Langseth, 2019; Palanivel, 2019). It spans documents such as birth certificates issued at birth to identity (ID) card issued governments. Higher education institutions also issue their registered students with identity cards that may contain a student name, degree program, age or date of birth, gender, race among other personal data. Additionally, the universities through various departments have to collate records of a student courses, transcripts, class attendance, scores, and credits throughout the student's life while at the institution in an analogue form.

The first challenge posed by such a system is vulnerability of the student information in terms of security and privacy. Many universities in South Africa usually gather and store student and alumni data with the aim of tracking where the graduates are for fundraising purposes. However, data protection issues that have plagued many institutions such as financial institutions, and medical institutions, among other large organisations, have posed a threat to the data stored by these higher education institutions as well. Notable examples in other countries such as the United States of America include hacking of the University of California–Berkeley, Ohio State University, the University of Wisconsin–Milwaukee, and Kirkwood Community College; Yale University accidentally publishing online of confidential information: unsecured storage of confidential information by Stanford University, University of Miami and University of Utah hospitals and clinics among others (Tapscott & Tapscott, 2017). It is imperative for higher education institutions in South Africa to take of these vulnerabilities (Moore 2019).

A possible solution to the first challenge is the use of a public key infrastructure (PKI), blockchain can be leveraged in capturing and storing identity and records in a secure (encrypted) and distributed ledger.

The second challenge is the issue of how to validate one's credentials This is because some graduates lie about or tamper with the certificates, transcripts and skillsets when applying for jobs. It is thus difficult for human resource practitioners to validate whether the credentials, transcripts and skillsets are correct. At times, there are cost implications when it comes to higher education institutions providing verified credentials and transcripts of the job applicants (Awaji, Solaiman & Albshri, 2020; Moore, 2019; Palanivel, 2019).

The possible solution to this challenge is the use of blockchain by means of which a student's credentials and transcripts can be accessed, shared, and downloaded securely by the student, the institution, and potential employers (*Figure 1: An example of blockchain system of how higher education institutions*).

Another challenge is that since not all who are admitted to study in universities manage to be full-time students, higher education institutions do not know how to reward some of the tasks part-time students engage in such as job in-service trainings. In South Africa in particular, this has been left to continuing professional development (CPD) schemes administered by professional organisations. However, blockchain technology can be used to offer digital badges detailing the skill set a part-time student learned while working and studying at the same time.

New pedagogy vs blockchain

Higher education systems draw recognition from the trust that society bestows on the certificates they confer and on the institutional processes leading to the conferment of the awards and certificates. This is what makes students pay to study at and obtain qualifications from these institutions(Vest, 2006). Some institutions have built reputations in this regard and the faith that society has in their processes and certificates which they confer is unshakable. Institutions that have not invested much into developing strong and incorruptible processes enjoy less high regard my students and society at large. However, for all institutions the pedagogy employed is under spotlight.

The model still largely employed by many higher education institutions follows an instructor-student model where the instructor broadcasts the information and the student does as the instructor directs, digests and apply the information through laboratory work and answering examination questions. This model has characterised by instructor notes exchanging hands from the instructor to the student without passing through the brains of either the instructor or the student. This pedagogy cannot blend with students immersed in digital technologies and thirsting to exploit the affordances of the Fourth Industrial Revolution. For these students, higher education is not just about acquiring credentials and skills, but rather also about communication and collaboration between their peers; ability to contextualise, solve and analyse real world problems; innovatively offer solutions to problem situations and the capacity to learn when, where and how they want (Chen *et al*., 2018; Sangai, 2018). Therefore, there are calls for a paradigm shift in the pedagogy in higher education institutions

Using blockchain, innovative pedagogies can be implemented in learning platforms that will meet the technological skill sets of students in age of the Fourth Industrial Revolution. Within such platforms, institutions will effectively administer courses, industries will be able to inform university curricula or offer courses tailored to their needs, the blockchain will ensure authenticity of the course content, accredit instructors, and provide provenance to courses offered. The students will also be able to study at their own pace without fear that their previous tasks and assignments will not count towards the certificates offered. In such a higher education system, everyone has a stake either directly or indirectly. Woolf University is renowned for such initiative that aims to meet this challenge. It is the first blockchain-powered, non-profit, borderless university that relies on blockchain and smart contracts between students and instructors. It has been considered in some circles as an 'Airbnb' of degree courses (Moore 2019).

Student debt (education cost) vs blockchain

Higher education is big business. This is evidenced by huge fees usually levied by higher education institutions on some of the courses offered by them that are deemed to be in high demand. These fees are usually charged irrespective of the student's financial status not forgetting that the student had to work extremely hard to qualify for the competitive courses. This leads to students either turning to financial aid or incurring student loans so as to meet the learning costs. Repayment of student debts

is also a challenge in addition to funders not able to ascertain whether the student completed the course and passed it.

In such instances, blockchain can be useful in establishing a funding mechanism like bitcoin where a student can easily access resources within a peer-to-peer setup; establishing a proof-of-truth mechanism to act as proof of a student's enrolment to courses, class attendance and completion of courses having met all the requirements; and establishing smart contracts within the peer network to facilitate student loan repayment.

Meta-university vs blockchain

As envisioned by Vest (2006), students in the age of the Fourth Industrial Revolution require a distributed learning ecosystem that facilitates real-time propagation of high-quality education, and gives both the instructors and students anywhere seamless access and sharing of instruction materials, scholarly publications, and scientific inquiry. The wait-and-see attitude adopted by some higher education practitioners is great disservice to the higher education sector. This is because implementation of blockchain technologies in higher education is no longer a pipe dream but rather a reality in practice. Three stages envisioned in such a setup entail (Tapscott &Tapscott 2017). Blockchain technology can be used in content exchange (free use of content as uploaded and shared online by instructors), content co-innovation (inter- and cross-disciplinary collaboration in creating content), and global network (fostering a global network of student, faculty, and universities). Hence, higher education institutions will no longer function as academic silos or islands that keep reinvesting themselves.

Conclusions

South African higher education institutions cannot continue to bury their heads in the sand when it comes to embracing and adopting the Fourth Industrial Revolution within their structures. Technologies driving the Fourth Industrial Revolution, such as blockchain, have significantly disrupted the financial sector and the ripple effect of this disruption will in the not so far future be experienced within the higher education sector. Since the goal of higher education is to prepare students for the jobs of the 21st Century and beyond, there is need for a change in the operation and management of higher education institutions. This can be achieved via leveraging the benefits of blockchain in student record storage and transfer, learning platforms, change in pedagogy and course content accreditation all of which can securely be done in distributed ledger system. Blockchain within the Fourth Industrial Revolution can offer borderless, seamless, and trusted quality education to individuals who would otherwise not be able to access quality education due to several factors including geographical location, financial and infrastructure constraints, among others. It is evident from the issues explicated above that, blockchain is one of the solutions that can address some of the issues plaguing higher education in South Arica and beyond.

References

Alam, T., & Benaida, M. (2020). Blockchain and Internet of Things in Higher Education. *Universal Journal of Educational Research* 8: 2164–74.

Awaji, B., Solaiman, E., & Albshr, B. (2020). Blockchain-Based Applications in Higher Education: A Systematic Mapping Study. In *Proceedings of the 5th International Conference on Information and Education Innovations*, pp96–104.

Chen, G., Xu, B., Lu, M., & Chen, N. (2018). Exploring Blockchain Technology and Its Potential Applications for Education. *Smart Learning Environments* 5(1).

Haugsbakken, H., & Langseth, I. (2019). The Blockchain Challenge for Higher Education Institutions. *European Journal of Education* 2(3): 41–46.

McGreal, R. (2021). How Blockchain Could Help the World Meet the UN's Global Goals in Higher Education. https://theconversation.com/how-blockchain-could-help-the-world-meet-the-uns-global-goals-in-higher-education-152885 (March 25, 2021).

Moore, S. (2019). 4 Ways Blockchain Will Transform Higher Education - Smarter With Gartner. https://www.gartner.com/smarterwithgartner/4-ways-blockchain-will-transform-higher-education/ (March 25, 2021).

Mzangwa, S. T. (2018). The Effects of Higher Education Policy on Transformation: Equity, Access and Widening Participation in Post-Apartheid South Africa. *Bangladesh e-Journal of Sociology* 15(1).

Mzangwa, S.T., & Dede, Y. (2019) The Effects of Higher Education Policy on Transformation in Post-Apartheid South Africa. *Cogent Education* 6(1): 1592737.

Ochara, N. M & Odhiambo, N. A. (2018). Sociomateriality of Digital Technologies in Collaborative Decision-Making Counter-Terrorism Contexts. In *ICMLG 2018 6th International Conference on Management Leadership and Governance*, 219.

Palanivel, K. (2019). Blockchain Architecture to Higher Education Systems. *International Journal of Latest Technology in Engineering, Management \& Applied Science (IJLTEMAS)* 8: 124–38.

Sangai, S. (2018). Higher Education Credit System Using Blockchain | by Sukant Khurana | Medium. https://medium.com/@sukantkhurana/higher-education-credit-system-using-blockchain-ca81e97c0be7 (March 25, 2021).

Schroeder, R. (2020). The Blockchain Future of Higher Ed. https://www.insidehighered.com/digital-learning/blogs/online-trending-now/blockchain-future-higher-ed (March 25, 2021).

Steyn, J. (2000). Balancing Quality and Equality in Educational Transformation. In *Democratic Transformation of Education in South Africa*, pp21–28.

Tapscott, D., & Tapscott, A. (2017). The Blockchain Revolution and Higher Education. *Educause Review* 52(2): 11–24.

Vest, C. (2006). Open Content and the Emerging Global Meta-University | Educause. https://er.educause.edu/articles/2006/1/open-content-and-the-emerging-global-metauniversity (March 25, 2021).

Towards a System of Governance of the Fourth Industrial Revolution Technologies in Higher Education Institutions

A. Kadyamatimba, & N. C. Ochara
Department of Business Information Systems
University of Venda
Corresponding author: armstrong.kadyamatimba@univen.ac.za

Abstract

This conceptual contribution explores the relevance of the Fourth Industrial Revolution technologies to the transformation and redefinition of corporate governance in general, and specifically to Information Technology Governance (ITG) in higher education institutions. The conceptualisation of the emerging system for the governance of the Fourth Industrial Revolution technologies draws from systems thinking, and specifically management cybernetics from which Stafford Beer evolved the Viable Systems Model (VSM) as a theory for diagnosing organisations. From a critical realist philosophical foundation, the VSM is applied to context of higher education institutions.

Keywords: Fourth Industrial Revolution, Governance, Viable Systems Model, IT governance, IT and organisational alignment

Introduction

The pace and scope of the Fourth Industrial Revolution continues to shape a new era, characterised by scientific breakthroughs and pervasive and increasing technologisation which has resulted in sometimes profound transformation of society. The Fourth Industrial Revolution, as a concept, affirms that technological change is a driver of transformation represented by a series of significant shifts in the way that economic, political, and social value is being created, exchanged, and distributed (Philbeck & Davis, 2019). These shifts in values are intimately related to the emergence of new forms of digital innovations that herald a need for a rethink of how our society is organised, and possibly, redesign governance practices and principles that evolved over the past centuries. It is important to have well thought-out governance systems in place for the Fourth Industrial Revolution because, while promising human advancement in many ways and the universality of the provision of services, the Fourth Industrial Revolution give rise to outcomes that entrench inequalities (Bertot, Estevez, & Janowski, 2016)public service delivery should be both universal, i.e. independent of the recipients' social or economic status, and contextualized, i.e. able to compensate for different local needs and conditions. Reconciling both properties requires various forms of innovations, chief among them innovations in digital public services. Building upon the four-stage model underpinning the United Nations e-Government Survey, the paper puts forward a framework for developing such innovations, and populates it with transparent, participatory, anticipatory, personalized, co-created, context-aware and context-smart services (including real-life examples. Therefore, there is a moral obligation that the adoption of the Fourth Industrial Revolution technologies and artifacts should be undergirded by a balanced governance system (UNIST, 2012).

As an artifact of human conception, the Fourth Industrial Revolution comprises a broad range of,

not only traditional information communication technologies (ICTs), but also artificial intelligence (AI), robotics, Internet of things (IoT), cloud computing, big data, fifth-generation mobile technology (5G), blockchain, 3D printing, robotics, or virtual/augmented reality (AR/VR), and machine learning technologies that are fundamentally changing the way human beings and human institutions organise work and relate to each other. Driven predominantly by digital technologies, this societal transformation taking place within the context of the Fourth Industrial Revolution presents a range of challenges, as well as opportunities. The expectation of society globally is that higher education institutions would be at the forefront of testing the Fourth Industrial Revolution technologies and recommending for adoption those that have proven benefits while cautioning society about those that have destructive effective. However, the involvement of higher education institutions in the discourses on the Fourth Industrial Revolution in general, and governance in particular, have not been substantial. This is not ideal the governance mechanisms assure the effective adoption and adaptation of technologies so that they guarantee public value.

The fixation on the multiple and fragmented Fourth Industrial Revolution technologies belie deep concerns about how to manage and govern these technologies. The consequence of the fixation on the technical aspects, almost to the exclusion of socio-cultural contexts, is fuelling a competitive race seeking to answer the question, 'Are we there yet', which was posed by Nankervis *et al.*, (2021). This fosters an incomplete understanding of the nature of the Fourth Industrial Revolution artifacts.

This paper contends that it is important to advance the Fourth Industrial Revolution technology taking into account the specific contexts of use; and that the governance mechanisms are also context specific. These contexts are diverse, complex, and unique which make the notion that the Fourth Industrial Revolution technologies universally bring about positive societal transformation, utopian. Avgerou (2001) suggests that advancing the Fourth Industrial Revolution technologies without considering contextual factors is only effective in spreading powerful messages about the significance of the technologies in the contemporary economy; but entails high risks of misguiding and frustrating local efforts to make sense and appropriate them. Lessons drawn from developing countries support this view as evidenced by the many failures of digital government innovations (Heeks, 2003; Mawela, Ochara & Twinomurinzi, 2017)"ISSN":"23137835","abstract":"© the author(s, with typical contemporary justifications linked to problems of management and governance (Damoah, Akwei, Amoako & Botchie, 2018), digital government innovation framing and professional conduct (Frost & Lal, 2018); a large digital divide, inadequate e-infrastructure and inadequate digital skills and competencies (Steyn, De Villiers, & Twinomurinzi, 2018; Twizeyimana & Andersson, 2019). We use the concept of artifact in the manner

Flowing from the above, this paper looks at the Fourth Industrial Revolution as a socio-technical artifact, as defined by Orlikowski and Iacono (2001), embedded in particular contexts, and how higher education institutions may assist in developing and advancing the necessary governance systems. The calls for the prioritisation of the development and advancement of the governance systems because adopting a *laissez faire* attitude towards the adoption of the Fourth Industrial Revolution technologies has the potential of reversing the gains of the last twenty-seven years in dismantling the legacies of apartheid.

The thinking that informs the paper is rooted in the theories of complexity and systems approach to understanding and resolving the problem of governance of the Fourth Industrial Revolution

artifacts and systems, leading to the formulation of possibly a first and unique conceptualisation of a governance system for the Fourth Industrial Revolution. The paper also presents a theoretical proposition and motivation for a viable systems approach to the governance of the Fourth Industrial Revolution, grounded on the Beer's Viable Systems Model (VSM).

Theoretical Development

The theoretical grounding for this study is developed by first reviewing and synthesising literature on IT governance in general; and then link IT governance mechanisms (as the focus of the study) to the governance of the Fourth Industrial Revolution artifacts. This is then followed by the theoretical underpinnings, anchored in systems thinking.

IT Governance and its link to the Fourth Industrial Revolution Governance Mechanisms

The focus of the paper is on governance systems that are developed for the Fourth Industrial Revolution digital technologies. These are developed from IT governance, which forms part of the broader corporate governance. While there are different conceptualisations of IT governance, there is general agreement that it operates at the level of corporate governance. The conceptualisation by De Haes and Van Grembergen (2009) represents this general agreement. They define IT governance as,

> ... integral part of corporate governance that addresses the definition and implementation of processes, structures and relational mechanisms in the organisation that enable both business and IT people to execute their responsibilities in support of business/ IT alignment and the creation of business value from IT-enabled business investments. (De Haes & Van Grembergen, 2009: 3)

In earlier discourses, IT governance used to be framed as a form of decision-making authority that can be based on decentralised, centralised or matrix forms. Further, such earlier discourses also outlined under which conditions these decision-making forms are chosen (Brown, 1997; Mohamad, 2018; Sambamurthy & Zmud, 1999). However, contemporary research, anchored in the conceptualisation of De Haes and Van Grembergen (2009) recognises intrinsic complexity and dynamism in the environment. Such research now recognizes that IT governance implementation consists of three governance mechanisms: structures, processes, and relational mechanisms (Aasi, Nikic, Li & Rusu, 2020; Caluwe & De Haes, 2019; Heroux & Fortin, 2018).

From a synthesis of literature, De Haes, Van Grembergen, Joshi & Huygh (2020) assert that IT governance structures are organisational units and roles responsible for making IT-related decisions and for enabling contacts between business and IT management (decision-making) functions (such as the IT strategy committee). Such committees provide a governance framework of how IT is structurally organised in an institution or organisation. IT governance processes relate to the formalisation and institutionalisation of strategic IT decision-making or IT monitoring procedures, to ensure that daily behaviour is consistent with policies and provide input back to decisions. For instance, the adoption and implementation of the IT balanced scorecard is an exemplar of the formalisation and institutionalisation of IT governance processes (De Haes et al., 2020). IT governance relational mechanisms are about the active collaborative participation and relationship among stakeholders and emphasizes the role of announcements, advocacy, communication channels and educational efforts (De Haes & Van Grembergen, 2009; Weill & Ross, 2004).

The integration of these three components provide a powerful interconnected IT governance arrangement that is linked to the performance of organisations (Wu, Straub & Liang, 2015). The link to organisational performance was confirmed in the research by De Haes & Van Grembergen (2009), in which they asserted that the implementation of processes, structures, and relational mechanisms, 'enable both business and IT people to execute their responsibilities in support of business/IT alignment and the creation of business value from IT enabled investments'(pp. 2-3). Thus, prior research has established that the three governance mechanisms (structures, processes, and relational mechanisms) provide a canvas for the meaning of IT governance and their role in enhancing business/IT alignment.

However, in providing a rationale for this study, it is recognised that the relationships of certain IT governance mechanisms and organisational performance have been examined, particularly with the organising vision of the Fourth Industrial Revolution becoming more entrenched in our society. More complete and solid empirical support for the three types of governance mechanisms identified and their relationships with strategic alignment is still missing from the Fourth Industrial Revolution literature. Table 1 summarises recent research on IT governance mechanisms on various technologies that form part of the Fourth Industrial Revolution. Though not exhaustive, the synthesis provided in Table 1 provide justification for continuing research that can explore, expose, and explicate the nature of governance of the Fourth Industrial Revolution.

Table 1: Summary Prior Research Related to the Fourth Industrial Revolution Governance Mechanisms

Study	The Fourth Industrial Revolution Technology	Research Purpose	Meaning of Governance	Findings
Hernandez-Perdomo, Guney, & Rocco (2019)	Machine Learning	Mapping corporate governance as a system	Corporate governance can be divided into internal and external sub-systems	Corporate governance is a complex system that can be mapped using machine learning
Meijer & Ubacht (2018)	Blockchain Technology	Conceptualise blockchain and provide insights into institutional arrangements and governance of blockchain systems	Blockchain environments and decision-making structures are highly decentralised.	Blockchain technology lowers control on blockchain systems for external actors or institutional frameworks, by engraining existing institutional structures into the technological design of the system

Study	The Fourth Industrial Revolution Technology	Research Purpose	Meaning of Governance	Findings
Beck, Müller-Bloch, & King, (2018); Ziolkowski, Miscione, & Schwabe (2020)	Blockchain Economy; Blockchain System	▪ Exploration of decision rights, accountability, and incentives related to governance. ▪ How blockchain systems are governed	▪ IT governance focuses on decision rights, accountability, and incentives. ▪ Organisational and economic coordination utilizing decision rights, incentives, and accountabilities	The blockchain economy's emphasis on decentralising decision rights and the technical enactment of accountability underscores the importance of incentive alignment.
Bygstad & Iden (2017)	Lightweight IT: Internet of Things; Robotics; BOYD	Discussion of governance models for lightweight IT.	Where decision making authority rests on decisions that encourage desirable behaviour in the use of IT	▪ Bimodal governance model, lightweight solutions are developed in separate processes but are subject to the heavyweight regime ▪ Laissez faire governance model to foster innovation. ▪ Platform governance model is useful for larger ecologies with platforms dominated by single actors

Study	The Fourth Industrial Revolution Technology	Research Purpose	Meaning of Governance	Findings
Hilb (2020)	Artificial Intelligence	Assesses the desirability, feasibility, and responsibility of automating board-level decision-making to ensure effective corporate governance	The system by which companies are directed and controlled	Proposes five scenarios of artificial governance, such as assisted, augmented, amplified, autonomous and autopoietic intelligence, that are likely to shape the governance of organisations today, tomorrow, and beyond
Hsu (2012)	Cloud Computing	develop a governance model to provide insights into how enterprises govern their cloud computing applications.	Proposition for a four-step procedure to establish a cloud computing governance model involving setting up: policies and standards; evaluation of risks; establishment of governance structures; evaluation of performance	Continuous learning is one of the successful factors in implementing a cloud computing governance model. Companies that understand the impacts of cloud computing and that can acquire skills necessary to set the proper security policies will be able to mitigate the risks associate with cloud security

The study by Hernandez-Perdomo *et al*., (2019) looked at the use of machine learning as a tool that can be used for effectively mapping corporate governance systems so as to enhance not only growth opportunities for organisations, but also organisational transparency. Therefore, the use of machine learning, as a Fourth Industrial Revolution resource is positively associated with organisational growth, as well as enhancing system transparency which is a key component of IT governance. Blockchain, which is another Fourth Industrial Revolution technology, is predominantly viewed as a system or an ecosystem in research. For instance, the study by Meijer and Ubacht (2018), looked at the institutional arrangements and governance of blockchain systems. Their study found that governance decision-

making structures of blockchain systems are highly decentralised and concluded that blockchain technology lowered control for external actors or institutional frameworks, by engraining existing institutional structures into the technological design of the system. Thus, blockchain technology enables the technological institutionalisation of values in environments that are highly dependent on the said values. Other studies on blockchain have approached it as an economic system (Beck *et al*., 2018; Ziolkowski *et al*., 2020). For instance, Beck *et al*., (2018) argue that established notions of IT governance are challenged when the blockchain is considered as an economic system. They motivate for governance in a blockchain economy that manifests in a new form of organisational design—decentralized autonomous organisations (DAO)—which are organisations with governance rules specified in the blockchain. Ziolkowski *et al*., (2020) on the other hand look at how blockchain systems are governed, and their conceptualisation of governance aligns with that of Beck *et al*., (2018). Their conclusions identify six decision problems linked to blockchain governance: the first two sit within the domain or old Information Systems (IS) research; while they also identified three new decision problems that are unique to the Fourth Industrial Revolution era that we find ourselves in. The six decision problems that they identify relate to problems of demand management, data management, system architecture design and development, membership, ownership disputes and transaction reversals.

The governance of the Internet of Things technology reported by Bygstad & Iden (2017) aligns with the meaning of IT governance proposed by Weill & Ross (2004). This focuses on where decision-making rights rest. They identify four approaches to governance, the first of which predominantly applies to traditional IT, with a highly centralised structure (central control model). They then make a case for three governance approaches that are relevant for lightweight IT such as the Internet of Things, robotics, and others. In the *laissez-faire* governance model, lightweight IT solutions are developed in cooperation between line managers and cloud vendors to foster faster innovation and user-oriented solutions. In the platform governance model, there is a negotiated division of labour, in which a centralised IT function encourages and supports lightweight IT initiatives. This model is useful for larger ecologies with platforms dominated. The bimodal governance model operates by having a separate IT management section that regulates IT initiatives, based on heavyweight technological policies and standards.

Other studies have also focused on the governance of artificial intelligence (Hilb, 2020) and Cloud Computing as a technology that forms part of the Fourth Industrial Revolution. Hilb's (2020) insightful study of artificial intelligence governance elevates the role of board-level decision making in effective corporate governance. He proposed five scenarios of artificial governance as captured in Table 1. Hilb (2020) believes that the propositions are not only relevant today but will be instrumental in shaping IT governance in the future as well. He sees the shift occurring at the interface between the mind and machine, which is likely to raise a whole new set of legal and ethical questions that touch the very substance of human will and self-determination. Further, since the technological possibilities of organisations to influence human thought will be greater and more difficult to control, their regulation will be highly controversial but also influential. However, the import in artificial intelligence governance is to shift the nature of organisations to be self-organising systems, where human intervention in governance will be minimal, but still required, as drivers.

Hsu (2012) studied governance of cloud computing, another of the technologies of the Fourth Industrial Revolution. His unique contribution is on a proposition for an IT governance, that prescribes a four-step procedure for realising effective cloud computing governance anchored on continuous learning

and a focus on security. The emphasis was on continuous learning as a call for contemporary entities to be learning organisations in the manner envisaged by Senge (1996). These are organisations with the ability to learn, adjust and change in response to new realities (Gephart, Marsick, Van Buren, Spiro & Senge, 1996). These new realities are evident with the adoption of the Fourth Industrial Revolution technologies.

In general, several themes can be identified from the literature reviewed above. The first, linked to machine learning in Table 1, is that aspects of the Fourth Industrial Revolution technologies are being used as tools to not only enhance the practice of IT governance, but also as an aid to entrenching corporate government as an organisational system. The second is the need for governance to be self-organising, which further fortifies the systems view of corporate and IT governance. Lastly, there are several approaches to governance, most of which tend to follow the decentralised models of corporate and IT governance of the Fourth Industrial Revolution technologies, though centralisation approaches still play a critical role in setting up enabling policies, standards, and common technological platforms. Then there is the issue of ethics which is important particularly when these the Fourth Industrial Revolution technologies are considered as tools and as self-organising systems, with increasing minimal human intervention. Ethical issues are increasingly falling under the domain of algorithmic accountability, in which governance systems that are partly self-organising are required to be more accountable, transparent and auditable (Gamito & Ebers, 2021).

It flows from the above that there is a need to re-look and redefine IT governance mechanisms that cover digital disruptions associated with the Fourth Industrial Revolution. The governance of the Fourth Industrial Revolution is, in essence, the governance of IT redefined as a self-organizing system, that incorporates the algorithmic accountability and use of the Fourth Industrial Revolution technologies for organisational sustenance and viability. This definition, evolving from the themes described above still recognises meanings associated with traditional IT governance, given that organisations still have extensive legacy digital infrastructures that still conform to the 'old way' of corporate governance. However, in the wake of the transformation of society in the wake of the Fourth Industrial Revolution, new conceptualisations of governance are necessary. Following this redefinition of IT governance, it is important that a new way of diagnosing the Fourth Industrial Revolution, which is firmly rooted in systems thinking, is developed, and operationalised.

Systems thinking and viable Systems

This study is grounded in systems thinking, a holistic approach to viewing components of dynamic systems. Systems thinking is pertinent because its principles, methods, and tools embrace the constancy of complexity in the behaviour of organisational systems, and its focus on providing practical solutions to problems and opportunities that face our contemporary society. For instance, Flood & Jackson (1991) propose a practical critical systems thinking approach for uncertain operating environments that emphasise a multiplicity of emancipatory approaches hinged on the tasks, tools and outcomes of creativity, choice and implementation methodologies (systems methodologies). While there are many models, theories and divergence in meanings associated with systems thinking (See Cabrera, Colosi, & Lobdell 2008; Peters, 2014) this paper uses the Beer's Viable System Model (VSM), which is grounded in cybernetics (Beer, 1979; Beer, 1984). The emphasis of VSM is on active learning and control. It offers useful lenses for understanding, explaining, and predicting systems that operate in highly uncertain environments, which is presently a constant in the operating environments of hgher education institutions. The essence of VSM is captured in Figure 1.

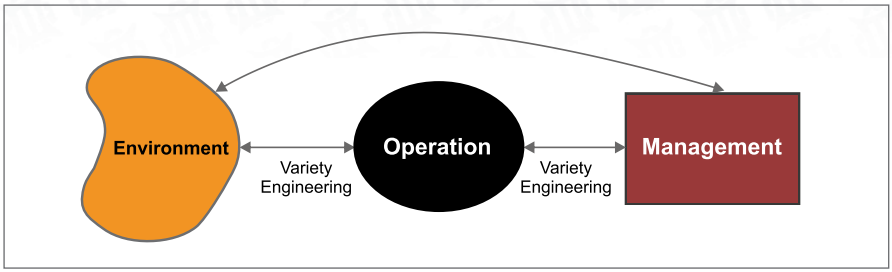

Figure 2: Essence of VSM (Adopted from Beer, 1985)

The theoretical grounding for VSM is in cybernetics (De Haes *et al*., 2020), an interdisciplinary discipline attributed to Norbert Wiener as the science of control and communication in the animal and the machine (Wiener, 1961). However, Ashby (1956) later positioned it as a science of complex systems. It is worth noting that Beer (1985) predominantly considered it as a theory of the organisation, translating its principles to the field of management, whence he described it as 'management cybernetics' (Beer, 1959), but also as the 'the science of effective organisation.' Therefore, the concept of management (Figure 1) draws from this thinking, in which attention is drawn to the oft ignored aspect linked to the management and/or governance of technical systems. Since then, cybernetics has captured the imagination of many, not only in disciplines in management, but also in technology-oriented disciplines, politics, and public policy. For instance, Kline (2006) quotes Margaret Thatcher, the former Prime Minster of the United Kingdom, who dedicated 1982 as the 'Information Technology Year, IT-82.' Therefore, the emergence of concepts such as IT need to be seen from the context of the emergence of systems thinking approaches such as cybernetics. Beer (1985) was a pioneer in pointing out that traditional management thinking did not embrace the concept of viability, thus, he ultimately translated the principles of cybernetics to evolve to VSM (Beer, 1985).

The entirety of Figure 1, therefore, captures the completeness of the essence of viability, a concept that Beers considers to relate to the capability of an organisation to have an independent existence, with the interaction of the three concepts of environment, operation and management (Beer, 1984). He expounds that a viable system exists within a dynamic environment that imposes a certain complexity on it. The viable system (entity, organisation), by implementing its organisational purpose (operation), and controlling its implementation (management), the viable system establishes establish *requisite variety*. Requisite variety is about complexity. De Haes *et al*., (2020) explain it as a state which is achieved when environmental, operational, and managerial complexities match. They logically argue that environmental complexity is much broader, followed by operational complexity and managerial complexity, in that order.

This logic captures Beer's conceptualisation of viability, and the meaning that emerges is that when requisite variety is maintained, the system will remain viable or continue to achieve its purpose. Key systems thinking gurus such as Ashby, Maturana and Varela gravitate towards the concept of autopoiesis or self-organisation (See Ashby, 1956, 1991; Varela, Maturana & Uribe, 1974) as a concept that is useful for the design of systems towards higher standards of viability, with the potential of making organisational digital technology artifacts more robust and adaptive. Thus, in the manner and interpretation of De Haes et al., (2020), establishing viability through self-organisation is achieved

through variety engineering. The dashed link between management and environment reflects the system's contact with its environment as well as the expectation of potential future states (Beer, 1985). Accordingly, variety engineering acts to enable requisite variety between environmental, operational, and managerial complexities. Hence, at a generic level, VSM is a dynamic model of organising that supports the design and diagnosis of effective control in organisations. Thus, when it was earlier alluded to VSM as a theory or model for understanding, explaining and predicting organisational forms, the idea was to present it as akin to Shirley Gregor's idea of a grand theory, that can be used for the study of '[…] what is, how, why, when, and what will be […]' (Gregor, 2006, p. 626). This paper makes use of the VSM as a grand theory to understand the 'what is' the Fourth Industrial Revolution governance in the context of higher education institutions. In the next section, building blocks for such an understanding are developed.

Towards a viable systems model for the Governance of the Fourth Industrial Revolution

The operating contexts and environments of higher education institutions are highly uncertain, which demands that their governance systems for the Fourth Industrial are robust and adaptive. The fundamentals of VSM outlined in the previous section provide an overview of it as a system. But there is need to recognise that within VSM as a system, there are five necessary and sufficiently interconnected sub-systems (system 1 through to 5) that account for overall viability of any system. Therefore, while mapping and developing the building blocks for the governance of the Fourth Industrial Revolution, the details of viability derive from these five sub-systems of VSM. First, Figure 1 is adapted into Figure 2 that draws on the theoretical parallels elucidated on earlier to link them directly to the nature of the Fourth Industrial Revolution technologies and the definition to the Fourth Industrial Revolution governance as presented earlier.

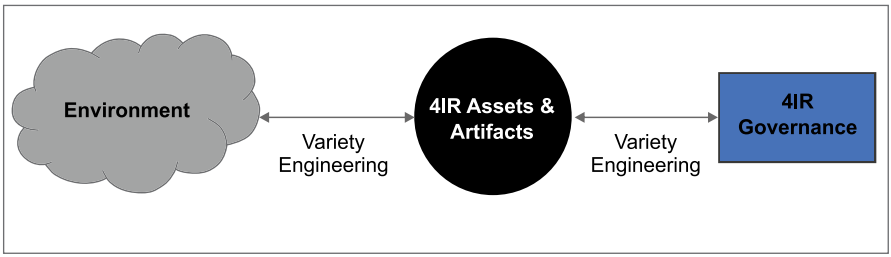

Figure 3: The Fourth Industrial Revolution Governance Requisite Variety (Adapted from Beer, 1985)

Table 2 below provides the theoretical parallels between the underlying concepts of VSM drawn from Figure 1 and mapped for relevance in the context of the Fourth Industrial Revolution (Figure 2), and delves deeper into the (sub)systems or functions, and communication channels or variety loops of the VSM in the manner of De Haes *et al.*, (2020). Figure 2 shows how the nature of a viable system applies to the Fourth Industrial Revolution artifacts in general; while Table 2 relates the sub-systems and communications channels of VSL relate to governance mechanisms that are relevant to Higher education institutions. De Haes *et al.*, (2020) assert that IT governance is anchored on cybernetics as a science of control. Following this logic, the governance of the Fourth Industrial Revolution is concerned

with the control over current and future the Fourth Industrial Revolution assets and technologies, thus the sub-systems of VSM and its communication channels are suitable for enhancing understanding of governance mechanisms within various contexts such as higher education institutions. The interpretations captured in Table 2 respond and consider VSM suitability in the understanding the governance of the Fourth Industrial Revolution.

Table 2. VSM and theTheoretical Parallels of Governance of the Fourth Industrial Revolution

VSM Underlying Concepts and their Relevance to the Fourth Industrial Revolution Governance		**References**
Viability	The purpose of the Fourth Industrial Revolution governance is to create and preserve value from 'digital' technologies. A Fourth Industrial Revolution governance system is viable when it accomplishes this purpose by leveraging the Fourth Industrial Revolution digital technologies and activities and controlling them.	Weill & Ross (2004)
Requisite Variety	Environmental complexity characterized by digital disruptions and digital transformation is the organisational norm. the Fourth Industrial Revolution Governance should be responsive to potential threats and opportunities so that requisite variety can be established, and viability is ensured.	Valentine & Stewart (2013)
Recursivity	Controlling digital assets and activities should be established at different levels of granularity (for example, at the inter-organisational level, corporate level, business domain level, project level, project task-level, and so forth)	De Haes & Van Grembergen (2015)
Transduction	Reducing communication distortion amongst organisational stakeholders involved in the Fourth Industrial Revolution Governance.	Hoverstadt (2020)
VSM Sub-Systems and their Relevance to the Fourth Industrial Revolution Governance		References
System 1	The reason for the existence of the Fourth Industrial Revolution Governance are digital assets and activities. The Fourth Industrial Revolution Governance (the Fourth Industrial Revolution governance system) should leverage digital assets and activities in a controlled way.	Weill & Ross (2004)
System 2	This represents the standards used as coordination mechanisms between, and within, the digital assets and activities.	Hoverstadt (2020)

System 3	This is the Command Axis responsible for ensuring that System 1 is a coherent and cohesive whole. Specific responsibilities include the Fourth Industrial Revolution assets management, assets performance measurement, and enforcing assets-related policies.	De Haes et al., (2020)
System 3*	Audits of the Fourth Industrial Revolution Assets (for example, project audits, security audits etc.)	De Haes et al., (2020)
System 4	Responsible for developing capability for environmental scanning for opportunities and threats related to, or in which the Fourth Industrial Revolution technologies can play a role to enable organisational agility.	Overby, Bharadwaj, & Sambamurthy (2006)
System 5	There should be evidence of direct or indirect involvement of the board of directors since the Fourth Industrial Revolution should be part of corporate governance to ensure its effectiveness.	Turel & Bart (2014)
VSM Communication Channels and its Relevance to the System for the governance of the Fourth Industrial Revolution		**References**
Environmental Communication	▪ Total environment through system 4 (viz. the Fourth Industrial Revolution governance transparency) ▪ Embedded environments through system 1 (for example, with software vendors or service providers).	Caluwe & De Haes, (2019; De Haes & Van Grembergen, (2009; De Haes et al., (2020)
Command Axis	The combination of the Fourth Industrial Revolution assets management, assets performance measurement, and enforcing IT-related policies (viz. responsibilities of system 3).	
Algedonic Channel	Used to raise alarm in the case of severe the Fourth Industrial Revolution digital assets related incidents (for example security breaches).	
S3 – S4 Homeostat	Considering the current situation (system 3) and the possible future states (system 4), this variety loop concerns the Fourth Industrial Revolution strategic decision-making. It is overviewed by system 5, to ensure that the outcomes of this process (for example, the Fourth Industrial Revolution strategic plan) are in line with the overall direction, values, and purpose of the system (for example, business strategic plan).	

The information presented in Table 2 above is used to motivate for the relevance of VSM in the governance system for the Fourth Industrial Revolution in higher education institutions in ensuing part of this paper.

Relevant Concepts for the Governance System for the Fourth Industrial Revolution

There is sufficient support in the literature for the theoretical parallels captured between the concepts of VSM and the governance of the Fourth Industrial Revolution captured in Table 2 above. For instance, VSM concepts that have been deemed relevant to the understanding the governance of the Fourth Industrial Revolution include: viability (Weill & Ross, 2004); requisite variety (Valentine & Stewart, 2013); recursivity (De Haes & Van Grembergen, 2015), and transduction (Hoverstadt, 2020). Viability applies to the purpose of the system for the governance of the Fourth Industrial Revolution for creating and preserving the 'business' or 'public' value of the Fourth Industrial Revolution assets or technologies. A system for the governance of the Fourth Industrial Revolution is viable when it continues to achieve this purpose by leveraging and controlling the Fourth Industrial Revolution assets and activities. When considering the viability of the system for the governance of the Fourth Industrial Revolution systems, higher education institutions need to consider the sources of value of various the Fourth Industrial Revolution technologies as it related to their contexts. Therefore, the mere adoption of the Fourth Industrial Revolution technologies such as cloud computing, artificial intelligence, machine learning, and many others, should not be the goal; but rather looking at how these various technologies can provide value in the context of the purpose of the organisation. Given the constancy of change, digital disruptions, and current turbulence in the higher education sector, requisite variety or variety engineering should seek to detect major sources of complexity and identify potential threats and opportunities for institutions to develop capabilities to respond adequately. Having a system for the governance of the Fourth Industrial Revolution with inbuilt and established requisite variety assures continuous viability. Transduction, a concept linked to having a shared language for enhancing communication in the organisation is aimed at reducing communication distortion in organisations. It is used in this paper in the sense conveyed by Ochara, Kandiri & Johnson (2014), who implore higher education institutions to use concerted efforts to forge a common conversational tone to reduce communication resistance and establish the credibility among key internal stakeholders. Thus, having a shared language is crucial to improve shared understanding between various stakeholders in organisations (Preston & Karahanna, 2009).

Relevance of VSM sub-systems to the system for the governance of the Fourth Industrial Revolution

The starting point in this section is to recollect that VSM views organisations as systems for managing variety. According to Beer (1985), such viable systems (also known as organisational systems) are made up of five specific types of (sub)systems (Figure 3). Below is a description of the sub-systems and teases out their relevance to the domain of the System for the governance of the Fourth Industrial Revolution, particularly in the context of Higher education institutions.

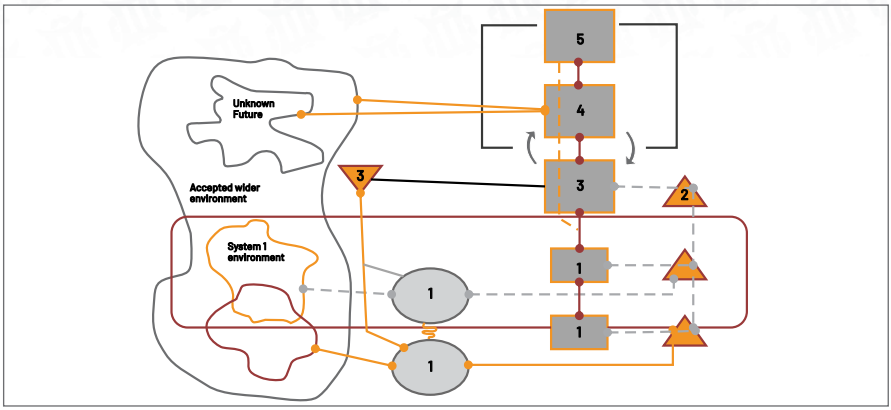

Figure 4: VSM Sub-Systems

Source: *Adopted from Beer, 1985*

System 1	The ***reason for the existence of the Fourth Industrial Revolution Governance are digital assets and activities.*** The Fourth Industrial Revolution Governance (the System for the governance of the Fourth Industrial Revolution) should leverage digital assets and activities in a controlled way.	Weill & Ross (2004)
System 2	This represents the ***standards*** used as c***oordination mechanisms between, and within, the digital assets and activities.***	Hoverstadt (2020)
System 3	This is the ***Command Axis*** responsible for ensuring that System 1 is a ***coherent and cohesive*** whole. Specific responsibilities include the Fourth Industrial Revolution assets management, assets performance measurement, and enforcing assets-related policies.	De Haes et al., (2020)
System 3*	Audits of the Fourth Industrial Revolution Assets (for example, project audits, security audits etc.)	De Haes et al., (2020)
System 4	Responsible for developing capability for ***environmental scanning for opportunities and threats*** related to, or in which the Fourth Industrial Revolution technologies can play a role to enable ***organisational agility.***	Overby, Bharadwaj, & Sambamurthy (2006)
System 5	There should be evidence of ***direct or indirect involvement of the board of directors*** since the System for the governance of the Fourth Industrial Revolution should be part of corporate governance to ensure its effectiveness.	Turel & Bart (2014)

System 1

System 1 covers an organisation's primary operational activities (operations and projects). In the entire organisation, there may be several operational activities, and in totality they provide the identity of the entity. Given that System 1 provides an identity to an organisation, they are the reason for the existence of the system for the governance of the Fourth Industrial Revolution. Typically, these systems derive from Business Units. For instance, in the case of higher education institutions, common Business Units are related to the major activities of Teaching and Learning; Research; and Operations, which would be managed by Deputy Vice Chancellors. Under each of these portfolios, specific activities would be defined for the delivery of the mandate of these Business Units. As higher education institutions transform in the wake of the Fourth Industrial Revolution, the mandates of these Business Units are to change as Fourth Industrial Revolution Projects take centre stage in the digital transformation process. A case in point is where several universities have commissioned face recognition projects to be used in examinations under the Teaching and Learning portfolio. The goal of a system for the governance of the Fourth Industrial Revolution is to leverage the different Fourth Industrial Revolution projects in a controlled manner to aid in the transformation of each individual higher education institution.

Under System 1 and its relevance to the system for the governance of the Fourth Industrial Revolution, the objective is to focus on better project management re-skilling as traditional project management skills have become increasingly insufficient for ensuring project success. There have been recent discussions that indicate that classic project management is becoming increasing ineffective (See Rodrguez-Rivero, Ortiz-Marcos, Ballesteros-Snchez, Mazorra & Snchez-Naranjo, 2021), and with the onset of the Fourth Industrial Revolution, an opportunity presents itself for a reflection on how to deliver better on the emerging the Fourth Industrial Revolution projects that will continue to redefine operations of higher education institutions. Effective re-skilling in project management can aid in better control of the many Fourth Industrial Revolution projects that are currently underway in various higher education institutions

System 2

System 2 is concerned with the direct coordination of System 1. Typical examples of System 2 are planning and information systems that connect dispersed business units. System 2 is necessary for avoiding 'oscillation', for example, the so-called 'bullwhip effect' in organisational value chains. For instance, in most higher education institutions, faculties are relatively independent units, yet the university still needs to function seamlessly as a whole. The role of coordinating systems therefore acts to dampen the inefficiencies associated with working in silos that are frequent and reminiscent of structural organisation of higher education institutions into faculties. Thus, from a system for the governance of the Fourth Industrial Revolution perspective, higher education institutions need to reinforce coordinating mechanisms through the development of common platform standards and policies, founded on the Fourth Industrial Revolution digital infrastructure to ensure organisational resilience. The use of the Fourth Industrial Revolution digital infrastructure to support and ensure the efficiency of organisational value chains have been developed in various sectors to address challenges such as the 'Bullwhip or Forrester Effect.' For instance, to address the information distortion in a logistics supply chain, Oh, (2019) proposes the use of artificial intelligence in the development of a smart supply chain; Bousqaoui, Achchab & Tikito (2017) advocate for the use of machine learning solutions to uncertainty and randomness in supply chains; while Manners-Bell & Lyon (2019) see a

big impact of the Fourth Industrial Revolution technologies in the re-organisation of the transportation function in organisations. These applications of the Fourth Industrial Revolution have potential in enhancing various coordinating activities of higher education institutions, and these exemplars can act as use cases for the beginning the transformation for higher education institutions to be more resilient and sustainable.

System 3

This is the 'Command Axis' responsible for ensuring that System 1 is a coherent and cohesive whole. Specific responsibilities include the Fourth Industrial Revolution assets management, assets performance measurement, and enforcing assets-related policies. These responsibilities are part of governance and relate to the resource utilization behaviour of 'System 1' as a whole. As a 'Command Axis', System 3 negotiates the resource-performance trade-off with each System 1, without jeopardiing their autonomy or the overall system's synergy (Mugurusi & de Boer, 2014). System 3 requires "System 2 information systems for the purpose of keeping interactions among System 1 within stable limits, as well as System 3*(system three star) [See Table 2] for dealing with unique problems in System 1 that require immediate attention to perform its function effectively. Thus, the overall focus of "Systems 3" is on the current situation or the current resource utilization situation, whose status is confirmed through undertaking frequent audits (System 3*)

In the context of the system for the governance of the Fourth Industrial Revolution in higher education institutions, attention is drawn to parallels between the concepts of Systems 3 and System 3* and resource utilisation command axis. Consider higher education institutions, where resource utilisation is devolved to the faculties, schools, and departments, in addition to the various support units. An understanding of current resource utilization from a bird's eye view is always changing without using various ISs (System 2). Typically, the 'Command Axis' from a structural perspective is undertaken by a Senior Management Committee (SMC) that draws from various representatives of units and relies on reports from representatives and ISs. However, the reporting on resource utilisation can be fragmented and fraught with misinformation. In essence, getting a clear picture of the current asset base and resource utilization for the entire system is problematic in most higher education institutions. Herein lies the opportunity for the use of the Fourth Industrial Revolution technologies to enhance, not only the reporting on asset utilisation, but also to enhance overall organisational productivity. For instance, Bartram, Branke & Motahari (2020) motivate for the use of artificial intelligence techniques in portfolio risk management, particularly since higher education institutions invest valuable assets, whose risk estimates are sometimes difficult to predict in advance. Thus, to minimise the risk of non-utilisation of assets, artificial intelligence techniques can be used to build risk profiles for various assets. Cloud computing has been proposed for implementing a less costly asset maintenance programs for certain classes of resources (Ala'a Al-Shaikh, Sharieh & Sleit, 2016); Big Data Analytics (BDA) (Maldonado, Cláudio & Pinho, 2020), and blockchain technologies (Schmitz & Leoni, 2019) are currently being used in auditing, a critical part of System 3*. Hence, various use cases are already emerging that are impacting the governance mechanisms related to the system for the governance of the Fourth Industrial Revolution, and igher education institutions can improve their overall corporate governance by adopting these the Fourth Industrial Revolution technologies to enhance resource utilisation.

System 4

System 4 is responsible for developing capability for environmental scanning for opportunities and threats related to, or in which the Fourth Industrial Revolution technologies can play a role to enable organisational agility. System oversees the scanning and identification of threats and opportunities in the environment. In an organisation, it may be associated with a Research and Development (R & D) unit; maybe devolved to the business units or may be handled at the board level. System 4 is concerned with the organisation's future viability and typically sees the need for continuous change. Due to this constant need for change and reform, Mugurusi & de Boer (2014) contends] that this creates a natural and ongoing tension between System 3 and System 4.

However, a concern for the future viability of an organisation is a key consideration in governance. But, in most higher education institutions, there is a noticeable lack of an R&D unit that concerns itself with the future viability of these organisations as currently constituted, particularly public universities that rely predominantly on government funding. And, as the Covid-19 has demonstrated, this approach to the management of public sector higher education institutions is unsustainable, and the rethinking of the future of education is inevitable (Cesco *et al*., 2021). The opportunities afforded by the Fourth Industrial Revolution technologies for reimagining the future of higher education institutions are well documented (du Preez & Sinha, 2021; Elayyan, n.d.; Jacome, 2021; Voskoglou, 2021), and the onus is on universities to setup R&D units that can reflect on the future operating models for Higher education institutions. Therefore, R&D becomes a critical sub-system for the governance of higher education institutions to evolve operating models that are in line with the dictates of the Fourth Industrial Revolution society.

System 5

System 5 oversees the maintenance of a proper balance between System 4 and System 3. This is typically top management of the organisation. There should be evidence of direct or indirect involvement of the board of directors since the system for the governance of the Fourth Industrial Revolution should be part of corporate governance to ensure its effectiveness. From a higher education institution's context, top leadership is typically represented by a Council and/or a Senior Management Committee (SMC). Little has been written about the preparedness of organisational leaders in embracing and adopting the Fourth Industrial Revolution in their institutions. However, to understand the relevance of System 5, it is proposed that leadership mentoring and executive education should be re-oriented to specifically address the impact of the Fourth Industrial Revolution on organisations of today. Thus, human capital leadership training takes on a new idimension, where the traditional skills set should include competency in, and appreciation of the role the Fourth Industrial Revolution technologies will henceforth play in the management and governance of higher education institutions. A re-think of the Fourth Industrial Revolution top management skills set is urgent since most Chief Executive Officers, Vice Chancellors and other leaders are trained in functional aspects of organising, which is sometimes unrelated to the real problems of the organisation, with priority on administrative techniques (Espinosa, 2020). Yet, the current open infrastructures founded on the Fourth Industrial Revolution technologies may call for a different skill set.

Conclusions

The Fourth Industrial Revolution is a new paradigm that can and will allow the re-imagination of corporate governance in general, and specifically IT governance towards a new form of digital governance: the system for the governance of the Fourth Industrial Revolution. The conceptualisation of the emerging system for the governance of the Fourth Industrial Revolution draws from systems thinking, and specifically management cybernetics from which Beer (1984) and Beer & Beer (1985) developed the Viable Systems Model (VSM) as a theory for diagnosing organisations. The paper has demonstrated how the VSM can be applied to the context of higher education institutions. The higher education sector is one of the critical sectors affected by the emergence of the Fourth Industrial Revolution technologies and systems. The VSM has been presented and discussed as a basis for understanding and explaining governance mechanisms for the Fourth Industrial Revolution technologies in the context of higher education institutions. The goals were to begin to entrench systems thinking, but specifically VSM for the redefinition and transformation of IT governance in higher education institutions, and thus a system for the governance of the Fourth Industrial Revolution.

References

Aasi, P., Nikic, J., Li, M., & Rusu, L. (2020). The Influence of Cloud Computing on IT Governance in a Swedish Municipality. *European, Mediterranean, and Middle Eastern Conference on Information Systems*,: 623–639

Ala'a Al-Shaikh, H. K., Sharieh, A., & Sleit, A. (2016). Resource utilization in cloud computing as an optimization problem. *Resource*, *7*(6)

Ashby, W. R. (1956). An Introduction to. *Cybernetics.* London*:* Chapman and U

Ashby, W. R. (1991). Requisite variety and its implications for the control of complex systems. In *Facets of Systems Science* (pp. 405–417). Springer.

Avgerou, C. (2001). The significance of context in information systems and organisational change. *Information Systems Journal*, *11*(1): 43–63

Bartram, S. M., Branke, J., & Motahari, M. (2020). *Artificial Intelligence in Asset Management*. CFA Institute Research Foundation

Beck, R., Müller-Bloch, C., & King, J. L. (2018). Governance in the blockchain economy: A framework and research agenda. *Journal of the Association for Information Systems*, *19*(10): 1

Beer, S. (1979). *The Heart of Enterprise*. Chichester: Wiley.

Beer, Stafford. (1984). The Viable System Model: Its Provenance, Development, Methodology and Pathology. *The Journal of the Operational Research Society*, *35*(1), 7. https://doi.org/10.2307/2581927

Beer, Stafford, & Beer, S. (1985). *Diagnosing the system for organisations*. Wiley Chichester.

Bertot, J., Estevez, E., & Janowski, T. (2016). Universal and contextualized public services: Digital public service innovation framework. *Government Information Quarterly*, *33*(2): 211–222. https://doi.org/10.1016/j.giq.2016.05.004

Bousqaoui, H., Achchab, S., & Tikito, K. (2017). Machine learning applications in supply chains: An emphasis on neural network applications. *2017 3rd International Conference of Cloud Computing Technologies and Applications (CloudTech)*,:1–7

Brown, C. V. (1997). Examining the emergence of hybrid IS governance solutions: Evidence from a single case site. *Information Systems Research*, *8*(1): 69–94

Bygstad, B., & Iden, J. (2017). A governance model for managing lightweight IT. *World Conference on Information Systems and Technologies*,: 384–393

Cabrera, D., Colosi, L., & Lobdell, C. (2008). Systems thinking. *Evaluation and Program Planning*, *31*(3): 299–310

Caluwe, L., & De Haes, S. (2019). Board Level IT Governance: A scoping review to set the research agenda. *Information Systems Management*, *36*(3): 262–283

Cardoso Espinosa, E. O. (2020). *Management Training Programs in Higher Education for the Fourth Industrial Revolution: Emerging Research and Opportunities: Emerging Research and Opportunities*. IGI Global.

Cesco, S., Zara, V., De Toni, A. F., Lugli, P., Betta, G., Evans, A. C. O., & Orzes, G. (2021). Higher Education in the First Year of COVID-19: Thoughts and Perspectives for the Future. *International Journal of Higher Education*, *10*(3)

Damoah, I. S., Akwei, C. A., Amoako, I. O., & Botchie, D. (2018). Corruption as a Source of Government Project Failure in Developing Countries: Evidence From Ghana. *Project Management Journal*, *49*(3): 17–33. https://doi.org/10.1177/8756972818770587

De Haes, S., & Van Grembergen, W. (2009). An exploratory study into IT governance implementations and its impact on business/IT alignment. *Information Systems Management*, *26*(2):123–137

De Haes, S., & Van Grembergen, W. (2015). Enterprise Governance of IT. In *Enterprise Governance of Information Technology* (pp. 11–43). Springer

De Haes, S., Van Grembergen, W., Joshi, A., & Huygh, T. (2020). Enterprise Governance of IT, Alignment, and Value. In *Enterprise Governance of Information Technology* (pp. 1–13). Springer

du Preez, J., & Sinha, S. (2021). A Paradigm Shift in Higher Education in the Context of the Fourth Industrial Revolution. *IEEE Potentials*, *40*(2), 13–18

Elayyan, S. (n.d.). The future of education according to the fourth industrial revolution. *Journal of Educational Technology and Online Learning*, *4*(1): 23–30

Flood, R. L., & Jackson, M. C. (1991). Total systems intervention: a practical face to critical systems thinking. *Systems Practice*, *4*(3): 197–213

Frost, D., & Lal, B. (2018). E-Government Project Design in Developing Countries. *International Working Conference on Transfer and Diffusion of IT*, 155–176

Gamito, M. C., & Ebers, M. (2021). Algorithmic Governance and Governance of Algorithms: An Introduction. In *Algorithmic Governance and Governance of Algorithms* (pp. 1–22). Springer.

Gephart, M. A., Marsick, V. J., Van Buren, M. E., Spiro, M. S., & Senge, P. (1996). Learning organisations come alive. *Training & Development*, *50*(12): 34–46

Gregor, S. (2006). The nature of theory in Information Systems. *MIS Quarterly: Management Information Systems*, *30*(3), 611–642. https://doi.org/10.2307/25148742

Heeks, R. (2003). Success and failure rates of eGovernment in developing/transitional countries: Overview. *IDPM, University of Manchester, UK* http://www. Egov4dev. Org/Sfoverview. Htm.

Hernandez-Perdomo, E., Guney, Y., & Rocco, C. M. (2019). A reliability model for assessing corporate governance using machine learning techniques. *Reliability Engineering & System Safety*, *185*: 220–231

Heroux, S., & Fortin, A. (2018). The moderating role of IT-business alignment in the relationship between IT governance, IT competence, and innovation. *Information Systems Management*, *35*(2): 98–123

Hilb, M. (2020). Toward artificial governance? The role of artificial intelligence in shaping the future of corporate governance. *Journal of Management and Governance*, *24*(4): 851–870

Hoverstadt, P. (2020). The viable system model. In *Systems Approaches to Making Change: A Practical Guide* (pp. 89–138). Springer.

Hsu, W.-H. L. (2012). Conceptual framework of cloud computing governance model-an education perspective. *IEEE Technology and Engineering Education (ITEE)*, *7*(2): 12–16

Jacome, F. E. (2021). Emerging Technologies and Universities: The the Fourth Industrial Revolution and the Future of Higher Education. In *Improving University Reputation Through Academic Digital Branding* (pp. 97–114). IGI Global.

Kline, R. R. (2006). Cybernetics, management science, and technology policy: The emergence of" information technology" as a keyword, 1948-1985. *Technology and Culture*, *47*(3), 513–535.

Maldonado, I., Cláudio, M., & Pinho, C. (2020). Big Data and Financial Auditing in Portugal. *2020 15th Iberian Conference on Information Systems and Technologies (CISTI)*:1–7

Manners-Bell, J., & Lyon, K. (2019). *The logistics and supply chain innovation handbook: Disruptive technologies and new business models*. Kogan Page Publishers.

Mawela, T., Ochara, N. M., & Twinomurinzi, H. (2017). E-government implementation: A reflection on South African municipalities. *South African Computer Journal*, *29*(1). https://doi.org/10.18489/sacj.v29i1.444

Meijer, D., & Ubacht, J. (2018). The governance of blockchain systems from an institutional perspective, a matter of trust or control? *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*: 1–9

Mohamad, S. (2018). National corporate governance codes and IT governance transparency. *Corporate Ownership and Control*, *16*(1), 13–18. https://doi.org/10.22495/cocv16i1art2

Muganda Ochara, N., Kandiri, J., & Johnson, R. (2014). Influence processes of implementation effectiveness in challenged information technology projects in Africa. *Information Technology & People*, *27*(3), 318–340. https://doi.org/10.1108/ITP-09-2013-0167

Mugurusi, G., & de Boer, L. (2014). Conceptualising the production offshoring organisation using the viable systems model (VSM). *Strategic Outsourcing: An International Journal*

Nankervis, A., Connell, J., Cameron, R., Montague, A., & Prikshat, V. (2021). 'Are we there yet?'Australian HR professionals and the Fourth Industrial Revolution. *Asia Pacific Journal of Human Resources*, *59*(1): 3–19

Oh, A.-S. (2019). Development of a Smart Supply-Chain Management Solution Based on Logistics Standards Utilizing Artificial Intelligence and the Internet of Things. *Journal of Information and Communication Convergence Engineering*, *17*(3): 198–204

Orlikowski, W. J., & Iacono, C. S. (2001). Research commentary: Desperately seeking the "IT" in IT research—A call to theorizing the IT artifact. *Information Systems Research*, *12*(2):121–134

Overby, E., Bharadwaj, A., & Sambamurthy, V. (2006). Enterprise agility and the enabling role of information technology. *European Journal of Information Systems*, *15*(2): 120–131

Peters, D. H. (2014). The application of systems thinking in health: why use systems thinking? *Health Research Policy and Systems*, *12*(1): 1–6

Philbeck, T., & Davis, N. (2019). The Fourth Industrial Revolution: Shaping a New Era. *Journal of*

International Affairs, *72*(1), 17–21. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=134748789&site=ehost-live

Preston, D., & Karahanna, E. (2009). How to develop a shared vision: The key to IS strategic alignment. *MIS Quarterly Executive*, *8*(1)

Rodrguez-Rivero, R., Ortiz-Marcos, I., Ballesteros-Snchez, L., Mazorra, J., & Snchez-Naranjo, M. J. (2021). The Logical Framework Approach, Does Its History Guarantee Its Future? In *Project Management and Engineering Research* (pp. 491–501). Springer.

Sambamurthy, V., & Zmud, R. W. (1999). Arrangements for information technology governance: A theory of multiple contingencies. *MIS Quarterly: Management Information Systems*, *23*(2), 261–290. https://doi.org/10.2307/249754

Schmitz, J., & Leoni, G. (2019). Accounting and auditing at the time of blockchain technology: a research agenda. *Australian Accounting Review*, *29*(2), 331–342.

Senge, P. M. (1996). Leading learning organisations. *Training & Development*, *50*(12), 36–37.

Steyn, R., De Villiers, C., & Twinomurinzi, H. (2018). Creating an ICT Skills Enhancement Environment for Entrepreneurs. *IFIP International Conference on Human Choice and Computers*,: 60–81.

Turel, O., & Bart, C. (2014). Board-level IT governance and organisational performance. *European Journal of Information Systems*, *23*(2),: 223–239.

Twizeyimana, J. D., & Andersson, A. (2019). The public value of E-Government – A literature review. *Government Information Quarterly*, *36*(2), 167–178. https://doi.org/10.1016/j.giq.2019.01.001

UNIST. (2012). *Realizing the Future We Want for All. Report to the Secretary-General*. United Nations New York, NY.

Valentine, E. L. H., & Stewart, G. (2013). The emerging role of the board of directors in enterprise business technology governance. *International Journal of Disclosure and Governance*, *10*(4): 346–362.

Varela, F. G., Maturana, H. R., & Uribe, R. (1974). Autopoiesis: the organisation of living systems, its characterization and a model. *Biosystems*, *5*(4): 187–196

Voskoglou, M. (2021). Computers and Artificial Intelligence in Future Education. In *Handbook of Research on Teaching With Virtual Environments and AI* (pp. 654–680). IGI Global

Weill, P., & Ross, J. W. (2004). *IT governance: How top performers manage IT decision rights for superior results*. Harvard Business Press

Wiener, N. (1961). Cybernetics. 1948. *New York*

Wu, S. P.-J., Straub, D. W., & Liang, T.-P. (2015). How information technology governance mechanisms and strategic alignment influence organisational performance. *MIS Quarterly*, *39*(2), 497–518

Ziolkowski, R., Miscione, G., & Schwabe, G. (2020). Decision problems in blockchain governance: Old wine in new bottles or walking in someone else's shoes? *Journal of Management Information Systems*, *37*(2): 316–348

Determinants of Cloud-based Cybersecurity within Higher Education Institutions

A. Kadyamatimba, N.N. Patala, S. Madzvamuse, & N. Ochara

Department of Business Information Systems

University of Venda

Corresponding author: Armstrong.Kadyamatimba@univen.ac.za

Abstract

The Fourth Industrial Revolution has accelerated the pace of innovation and digital transformation. Cloud computing is one of the Fourth Industrial Revolution technologies that are being increasingly adopted by higher education institutions. However, research on securing cloud platforms and resources is nascent in the context of higher education institutions, as cybersecurity remained a serious risk in the adoption of in cloud computing. This paper reports about a study that was undertaken at the University of Venda to inform the development of a framework that can guide higher education institutions in the development and implementation of strategies to make cloud computing secure.

Keywords: Cloud computing, cybersecurity, cloud-cyber security benefits

Introduction

The Fourth Industrial Revolution has transformed organisations that have embraced its suite of technologies like additive manufacturing, robotics, digital services, and the Internet of Things. It is part of a growing trend of leveraging the convergence of these emerging technologies (Maynard, 2015). Within the computing domain, the technologies that characterize the Fourth Industrial Revolution include artificial intelligence, machine learning, blockchain, cloud computing, Internet of Things (IoT), fifth generation mobile technologies and robotics. As a result of the increasing pervasiveness of these the Fourth Industrial Revolution technologies, the organisational environment is also changing, with increasing risks and threats linked to these technologies. For instance, the World Economic Forum has reported increased data and privacy risks posed by the increasing proliferation of the Fourth Industrial Revolution (Waughray et al., 2018). The security risks are even much more explicit and widely reported for specific technologies of Fourth Industrial Revolution such as cloud computing.

Higher education institutions in South Africa have adopted cloud computing, and are therefore face the risk alluded to above (Qasem et al., 2019). They are using cloud technology to improve their digital visibility. They are dependent on information technology for managing and administrating their daily operations, thus making them amongst the key sectors using cloud technology for its activities. Cloud computing has proven to have a positive effects on the academia as it allows students, academics, department and administration staff to obtain numerous educational and research content, apps and tools online (Cieplak & Malec, 2014). This places higher education institutions under immense pressure to maintain high standards of IT-related service delivery on or off campus (Chibaro, 2015). One of the key activities in this regard is monitoring and mitigating the security risks associated with cloud computing.

Notwithstanding the significant benefits of cloud computing as detailed in the study of Patala, (2017), various challenges have arisen within the cloud environment (Alshamaileh, 2013). Ensuring cybersecurity is a challenge faced by the users, and therefore before migration to cloud computing, it is essential to consider the cybersecurity arrangements. The possibility of attacks through the internet is becoming a threat for e-students and this influences their cloud adoption decisions (Kumar & Chelikani, 2011). Cybersecurity risks are much pronounced in the cloud computing environment with bolder data breaches happening at alarming rates (Bromiley, 2017; Sterbenz, 2017). Higher education institutions in the United States of America have confirmed being victims of cyber security breaches in their cloud computing environments (Ulven, 2021). Cyberattacks within the cloud is no longer a question of 'if they will happen, but rather of when they will happen. The attackers are now implementing innovative methods for breaking the security of well-established institutions (E&Y Inc., 2015). Therefore, higher education institutions are concerned about the security of their cloud computing environments (Ulven, 2021; Tout et al., 2009).

Cyberattacks keep transforming the risk landscape as institutions cannot determine exactly what type of cyber-attacks are to emerge within the next 5 to 10 years' time. However, the most common domains prone to cyberattacks in higher education institutions are surrounded within e-mail, e-learning, and library systems. Since countries usually regulate their cyber environments using their different policies, it has been a challenge to resolve cross-border cyber issues due to an absence of global cyber laws, thereby hampering the cybersecurity efforts (Jaquire, 2015). Odeh (2017) asserted that security and privacy are the main barriers that negatively affect the adoption of cloud computing in higher education institutions in developing countries and these include South Africa.

Currently, there are no one size fits all solutions to various levels of cloud computing security issues. The problem of the current research is that there is no guidance available that specifies the requirements that need to be considered in the adoption of cloud-based cybersecurity within higher education institutions in South Africa. The study reported in this paper attempted to develop and propose a framework that higher education institutions can utilize in enhancing the usage of cloud-based cybersecurity within their respective environments. The framework can be used as a reference point in making decisions.

The frameworks currently used in industries were analysed to determine if they could be modified for use within the context of higher education institutions. It was discovered that most industries have frameworks that focus on cloud computing security and cybersecurity as to independent factors, which is not helpful. Therefore, there was a need to merge these two factors into one.

The objective of the study reported in this paper was to determine the factors that influence the adoption of cloud-based cybersecurity within higher education institutions in south Africa by determining (a) the drivers for cloud-based cybersecurity usage and adoption in higher education institutions, (b) how cybersecurity benefits affects cloud usage and adoption decisions within the higher education institutions, (c) the quality perceptions of cloud-based cybersecurity, and (d) the level of awareness of key stakeholders within higher education institutions. At the end, the study also sought to propose a robust cyber-security framework for adoption of cloud computing in higher education institutions.

After the introduction and background presented in the preceding paragraphs, this proceeds to present related works from available literature followed discussion of the conceptual framework and methodology. The subsequent sections discuss the findings of the study, the proposed framework, and the contributions of the study followed by conclusion.

Related works

This section reviews the literature on cloud computing security and cybersecurity.

Benefits of cloud computing security

Although numerous risks have been identified in the cloud environment, service providers are continuously provisioning additional security with the aim of meeting the expectations of their clients and maintaining their reputations (Fumeaux, 2016). The following security benefits have been recognised by Haeberlen and Dupré (2012).

- Security and the benefits of scale: since the benefits are provided on a larger scale, the cost of security implementation measures becomes inexpensive. The costs may involve patch management, VM and hypervisor sensitivity maintenance, security personnel management, and identity management.
- Security as a market differentiator: cloud providers also offer Security-as-a-Service which is a strong driver for improved security measures. Users often tend to utilise services solely on the reputation of providers confidentiality and integrity strength and competency.
- Rapid smart scaling of resources: cloud vendors have the abilities to dynamically reallocate resources for filtering, traffic shaping, and encryption as a solution to limit the effect of attacks and attain a sustained defensive measure.
- Audit and evidence gathering accommodates service providers with relevant risk management measures without affecting the performances. This is due to logs storage being provided thorough offline forensic analysis.
- Standardized interfaces: services providers have the capabilities for providing a standard open interface for managing security services with Security-as-as-Service being readily available at a reduced cost for users.
- Data backup and storage: the traffic on the primary network is reduced as a different network is used for backup servers.

Cybersecurity trends within higher education institutions

Several higher education institutions in South Africa are engaged in an initiative of endorsing cybersecurity culture as part of their community engagement activities. Table 1 presents summary information about higher education institutions' successful engagement with cybersecurity awareness programmes.

Table 1: Cybersecurity Awareness Initiatives at some South African higher education institutions

SA CSA Initiatives	Activities	Target Audience
University of Pretoria: ICSA	▪ Running PumaScope project annually as part of University of Pretoria's cybersecurity awareness initiative (Grobler et al., 2011). ▪ Information and cyber-security roadmap is published on the UP website as part of the security awareness campaign with multiple articles exploring various cybersecurity themes with the aim to ensure UP has informed staff and students that could protect the university from security attacks (Mmthembu, n.d.). ▪ Cybersecurity I, a short course offered by University of Pretoria to provide first-hand exposure to the basics of cybersecurity (Enterprises University of Pretoria, n.d.).	- Rural schools - University members
University of Fort Hare	▪ Testing student's level of competency in understanding information security, as they may be aware of the cybersecurity issues but might not respond to the knowledge obtained (Grobler et al., 2011). ▪ University of Fort Hare collaborated with the National Consumer Commission in launching a Social Consumer Law course with the aim of spreading awareness on social security and cyber security laws (Aretha, 2020).	1st and 3rd year university students.
Nelson Mandela University	▪ Reporting on various elements of information security management and creating cybersecurity culture, education and awareness (Dlamini & Modise, 2012). ▪ Created a centre for research in information and cyber security (CRICS) with publications and reports on various aspects of cybersecurity. CRICS aims to focus on security aspects of cyber citizenship.(Centre for Research in Information and Cyber Security., n.d.)	Nelson Mandela University/company end-users, entrepreneurs, children, parents, tertiary and senior citizens
University of South Africa	▪ Contributing in creating cyber awareness culture, educating people, and enabling them to realize their responsibility of securing their computers (Dlamini & Modise, 2012). ▪ Initiated a Cyber Security Awareness Community Engagement Project (CSACEP) to cultivate cyber-awareness culture among children in South Africa (UNISA, 2017). ▪ Created an initiative to equip school-children and parents about cyberspace by targeting Government Schools and Community-based NGOs (Mkhize, 2021).	School children
University of Venda	▪ Engaging with entities such as CSIR in initiating cybersecurity awareness and address cybersecurity challenges in South Africa (CSIR, 2012; Dlamini & Modise, 2012)published by the Multi-State Information Sharing and Analysis Center (MS-ISAC. ▪ Initiated a cybersecurity awareness campaign to create a strong and healthy cybersecurity culture and promoting knowledge about cyber threats (Khoza, 2021).	Students, internet, and computer users in Venda.

Cloud-based cybersecurity drivers in higher education institutions

The Portland State University developed a roadmap for its cybersecurity within the cloud environment with the aim of advancing cybersecurity technology and practices (Loanzon, 2014). A set of cybersecurity drivers as summarised in Figure 1 were identified with the aim of developing a secure cloud environment for higher education institutions in the short and long run. The figure contains five significant drivers briefly described as follows:

Security and privacy are significant drivers for cybersecurity for an on-site computing environment. However, in a cloud computing setting, the significance is elevated. Higher education institutions ought to collaborate with state agencies to acquire network infrastructures that are more secure. This driver also enables to integrate tertiary institution's security activities with national security activities.

Legal and regulatory compliance highlights national alliances of cybersecurity in higher education institutions. Compliance with various regulations and Acts has a positive impact on higher education institutions.

Financial cost is also an important driver in keeping up with technological developments. Higher education institutions are required to invest in adequate equipment and software to support appropriate cybersecurity models and technologies.

Keeping up with technology plays a substantial role as the Bring Your Own Device (BYOD) trend requires higher education institutions to introduce proper mobile device security management. Additionally, accessing resources from cloud computing on personal devices rather than on-site work on computers, accelerates the adoption of cloud computing.

Public reputation is significant since higher education institutions are vulnerable to cybersecurity breaches which can lead to a negative publicity leaving an impact on tertiary institution's reputation and public trust.

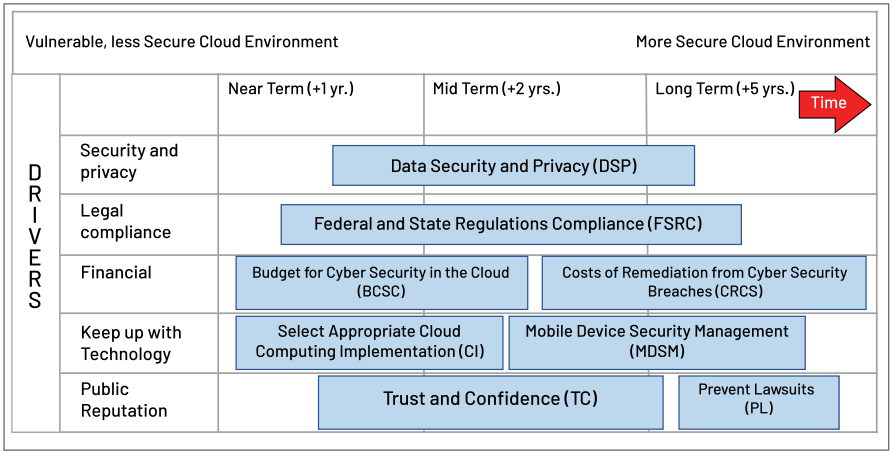

Figure 1: Cybersecurity drivers for cloud computing in higher education

Cloud-based cybersecurity requirements for higher education institutions

The security requirements of any cloud computing platform ought to be in compliance with the elements of the software, platform, and infrastructure (SPI) model as summarised in Figure 1 (SSH Communications Security, 2017).

Table 2: Cloud cyber security requirements

Software as a service (SAAS)	Platform as a service (PAAS)	Infrastructure as a service (IAAS)
Security on access control Communication protection	Access controls Security for applications	Hardware security Hardware reliability
Software security	Secure data image	Network resource protection
Service availability	Virtual cloud protection	Infrastructure control
Delegation control	High availability	Robust isolated sharing
Privacy is a multitenant environment	High scalability	High scalability with on-demand infrastructure provisioning
	Sharing with strong isolation	

Existing cybersecurity frameworks

For identifying and understanding various elements within a cybersecurity framework, it is important to study and review the existing available cybersecurity frameworks, writings and documentations by regional bodies and expert organisations as presented in Table 3. It also aided determining if any of them could be suitable to be modified as a cloud cybersecurity adoption framework.

Table 3: Existing Cybersecurity frameworks and writings

Framework/ Documentation	Objective	Key Themes
International telecommunications union (ITU) framework Invalid source specified..	Providing guidance for cybersecurity in developing countries.	▪ Government cybersecurity accountability ▪ Organisational structures for national cybersecurity focal points and crime units ▪ Technical, procedural, and legal measures ▪ Capability building of cybersecurity skills, training, assurance, monitoring and international cooperation.
NIST cybersecurity framework (AWS, 2017).	Provide simple and effective constructs of three elements namely: core, tier and profile.	▪ The core structure consists of five risk management functions namely: identify, protect, detect, respond, and recover. ▪ The tiers provide baseline a baseline for manging cybersecurity risks. ▪ The profiles determine the organisation 'as is' and 'to be' risk posture.

Framework/ Documentation	Objective	Key Themes
Cybersecurity risk management and threat control model (Uudhila, 2016)	Enhancing the protection of Namibian public sector.	▪ Cybersecurity threat control, risk management ▪ Vulnerable information assets, external/ internal security controls, uninterrupted service and residual risks ▪ Security policy framework which covers security best practices, audit compliance, user education and awareness.
African union on cybersecurity and personal data protection (African Union, 2014).	▪ Promoting cybersecurity and -Providing measures for combating cybercrime in e-commerce. ▪ Highlighting the requirement for national cybersecurity framework	▪ Protection of personal data of consumers ▪ Security of electronic transactions ▪ Providing monitoring structures for national cybersecurity (thus, cybersecurity governance) ▪ Legislative measures
ENISA guidelines on national cybersecurity strategies (Enisa, 2012).	▪ Aiding in identifying an integrated approach for national risk management ▪ Improving training and education for specialists in information security with a focus on current and future security and reliance issues	▪ Defining cybersecurity governance framework ▪ Identifying critical information infrastructure ▪ Diminishing cybercrime effects ▪ Provide means of developing national capabilities ▪ Provide means to improve response and recovery plans

Existing cybersecurity policies and strategies

The identified national cybersecurity policies implemented in numerous countries are summarized in Table 4.

Table 4: Global cybersecurity policies and strategies

Cybersecurity Policy	Key Elements
South Africa	▪ Establish and facilitate structures for supporting cybersecurity ▪ Ensuring cybersecurity threats and vulnerabilities are reduced ▪ Promoting corporation and coordination amongst government and private sector ▪ Endorsing and strengthening international cybersecurity corporation ▪ Building capacity and encouraging cybersecurity culture, ▪ Promoting compliance with operational and technical cybersecurity standards.
India	▪ Generating adequate trust and confidence in IT systems and cyberspace transaction ▪ Creating an assurance framework for security policies ▪ Enhancing the protection of national critical information structure ▪ Developing indigenous security technologies

Cybersecurity Policy	Key Elements
Malaysia	▪ Policy consists of frameworks concerning legislative and regulatory, governance, cybersecurity technology, compliance and enforcement, cybersecurity emergency readiness and cooperation. ▪ Addresses the cyber aspects concerning public/private cooperation, legislation, regulatory, technology and international relations. ▪ Addresses the national information infrastructure containing the integrated information systems of ten sectors in Malaysia namely: transportation, banking, health, energy, agriculture & foods, water, emergency services, ICT, government and national security defence
Cybersecurity strategy	**Key Elements**
Germany	▪ Protection of critical information infrastructure, ▪ Securing national information services ▪ Securing IT in public administration, ▪ Sustainable implementation and personal development in federal authorities ▪ Developed a national cybersecurity response centre and council
Japan	▪ Eliminate cyberattacks through social and economic development, crises management, national security, safety and security of public ▪ Assurance of free flow information, ▪ Strengthening risk response measures, ▪ Construction of resilient cyberspace, ▪ Strengthening the recognition of information sharing measures in private companies and educational institutions, ▪ Implementing preventative measures for a hygienic cyberspace, ▪ Defending and developing countermeasures of crime within the cyber space, and ▪ Strengthening capabilities of Japan-related state level cyber-attacks
India	▪ Creating a secure cyber-ecosystem ▪ Creating mechanisms for security threat warnings and vulnerability management ▪ Creating cybersecurity awareness ▪ Promoting cybersecurity culture

Cloud computing security standards

Numerous cloud vendors use a common mandatory method such as obtaining trusted security certifications and audits for potential clients with the aim of protecting client data due to an absence of uniform and unsettled cloud security standards (Kajiyama, 2012). Various globally accepted information security standards are present; however, it did not address the particular security issues recognized in cloud technology (Tripathi & Mishra, 2011). The following standards were identified to have a maximum direct effect on cloud computing security:

- Federal Information Security Management Act (FISMA): it is an obligation of federal institutions to develop, document and implement a program to ensure the security of information systems (NIST, 2016). Cloud providers accredited with FISMA would automatically be in compliance with regulations that federal agencies need to follow to achieve data security.
- Payment Card Data Security Standard (PCI-DSS): offers a framework to cloud providers

for hosting applications that requires a powerful data security process for card payments (Security standard council).

- Health Insurance Portability and Accountability Act (HIPAA): demands that every health care organisation occupied with protected health care information abides firm information security guidelines of HIPAA (Kajiyama, 2012). Although the guidelines are not directly executed on cloud providers, they ought to be in compliance with HIPAA and govern secure policies and infrastructure satisfying HIPAA Standards in a case where healthcare organisations require to store sensitive information in the cloud.
- ISO27000: contains general security standards that does not cater addressing all the aspects of cloud. Although security needs for cloud computing are distinctive, it is significant for security needs to be aligned with security standards as the ISO27000.
- NIST Cloud Computing Standards Roadmap: traditional security processed and mechanisms can be used to address most cloud security issues, but where standards for particular security process does not exist, NIST and numerous and US industry leaders are working on designing standards to cater security in the cloud environment (Annie & Michael, 2013).

Conceptual framework

The requirement of using theory as a conceptual basis in information security research is encouraged in various literature (Costello *et al*., 2013; Phillips, 2007). The conceptual framework enabled to build a research foundation and provided support for the research design, methods, and instruments employed in the study (Maxwell, 2004). The underpinning theories of the current study were adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT) model and the Information Systems Success (ISS) model. The ISS model enabled to determine the effectiveness and success of cloud-based cybersecurity adoption, while the UTAUT model enabled to present a more comprehensive overview of cloud-based cybersecurity acceptance (Chibaro, 2015). The unified framework attempted to combine the quality dimensions from ISS model with the UTAUT model as antecedents for the intention of use with an effort to disclose the role of quality in using cloud-based cybersecurity in higher education institutions. It should be noted that the systems, information, and service quality constructs from the ISS model were merged into a single construct as quality for this study. Three additional constructs namely cybersecurity drivers, benefits and awareness perceptions were added to the framework to meet the objectives of the study. Moderators such as age, gender and information systems experience were added to determine their impact on adoption decisions. As suggested by (George, 2015), the conceptual framework for this research is illustrated in Figure 2 representing the significance of each construct to the study.

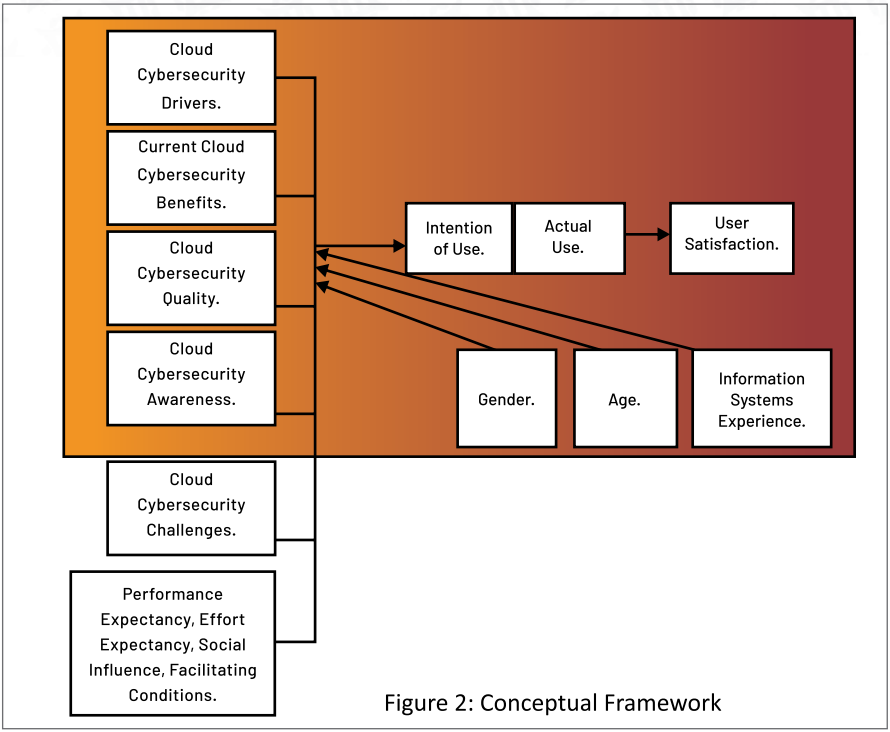

Figure 2: Conceptual Framework Derived from UTAUT and ISS Model

The research model in Table 5 illustrates the interdependence of the research constructs.

Table 5: Research Model

Research Model	
UTAUT/ ISS Theory Constructs	**Description**
Cloud Cybersecurity Drivers	Cyber security drivers represent perceived factors contributing to the adoption of cloud cybersecurity. The degree of factors contributing towards adoption was achieved by measuring perceived improved data and information security, financial reasons, the pace of keeping up with technology, maintaining the public reputation and legal law and regulatory compliance.
Current Cloud Cybersecurity Benefits	Was measured in terms of perceived benefits of using cloud cybersecurity.
Cloud Cybersecurity Quality	Quality of cloud cybersecurity was measured as the degree of information, service, and system quality of using cloud-cybersecurity. The degree of information, service, and system quality in this study was achieved by measuring the perceived responsiveness, relevance, reliability, accuracy, and value of cloud cybersecurity to members of the higher education institutions.

Research Model	
UTAUT/ ISS Theory Constructs	**Description**
Cloud Cybersecurity Awareness	Was measured as the degree of awareness individuals in the tertiary institution has regarding cloud cybersecurity. The degree of awareness in this study was measured through perceptions regarding the risks and opportunities of cloud-cybersecurity, awareness, and training programmes
Intention of use	It is the factor determining the acceptance or rejection of the cloud cybersecurity technology and the perceived satisfaction higher education institutions cloud achieve from adopting the cloud cybersecurity
User satisfaction	This is the perceived satisfaction higher education institutions could achieve from adopting the cloud cybersecurity
Age, Gender, Information systems experience	Enabled to determine their role and influence towards the adoption and usage of cloud cybersecurity

Research Methodology

The study followed objective epistemological assumptions to generalise and determine common content and predict patterns of adoption behaviour among the university stakeholders (Introna, 2015). A positive theoretical perspective and a deductive approach was followed which aided to discover casual relationships among cloud cybersecurity constructs and its adoption in higher education institutions (Neuman, 2009). A survey research design was adopted because the study aimed to collect information from more than one cluster of a large population within the University of Venda (Fowler, 2009). The data was collected from students, staff, lecturers. The cross-sectional research design was employed to obtain data in a particular short period of time through questionnaires (Hall, 2011). A quantitative approach was employed to generate quantifiable data concerning the factors influencing the adoption and use of cloud-based cybersecurity services (Alharbi, 2016). Probability sampling was used as a method for obtaining a representative sample as it enabled to set parameters for ensuring that the lecturers, admin staff and students have a known zero probability of being chosen (Chibaro, 2015; Fink, 2016). Non-probability sampling was used to gain data from the IT personnel because the researcher believed them to have specific knowledge that could add value to the study (Bacon-Shone, 2015). Simple random sampling technique was used as each element of the population was relatively homogeneous (Alvi, 2016). The sample size comprised of 255 participants from the University of Venda. The data collection instrument used was structured questionnaires (close-ended) as it allowed the participants to communicate their views easily and anonymously on the usage of cloud cybersecurity in higher education institutions (Liya, 2014). The data analysis method was descriptive in the form of frequencies and percentages which enabled to identify patterns, describe respondents profiles and factors which facilitated the adoption of cloud cyber-security (Alshehri, 2012).

Results

Demographic Information

255 questionnaires were distributed to the respondents of which 228 were received. The demographic data was significant as it could have an influence on the study results and play an important role in determining the perceptions of respondents towards the adoption of cloud-cybersecurity. The

demographic results consisting of age, gender and race are presented in Table 6. The results indicate that majority of participants were female students (51.8%), the dominating age group was 15-25 (51.1%) and more than 90% of participants were African blacks.

Participant's Demography			
Measure	**Items**	**Frequency**	**Percent**
Gender Distribution	Male	110	48.2%
	Female	118	51.8%
Age Distribution	15-25	124	55.1%
	26-35	57	25.3%
	36-45	28	12.4%
	46 and above	16	7.1%
Race	African Black	209	91.6%
	Coloured	5	2.2%
	Asian/Indian	7	3.1%
	White	7	3.1%

Table 6: Demographic Data

Drivers for cloud cybersecurity usage and adoption.

The respondents were asked to rate their level of agreement or disagreement concerning their opinions on cloud cyber- security drivers on a scale of 1-5. The drivers of adoption were identified and used from a study conducted by (Loanzon, 2014a). The results are depicted in Table 7.

Table 7: Drivers of cybersecurity

	Drivers for Cloud-Cyber Security Adoption						
	Drivers		**SA**	**A**	**N**	**D**	**SD**
D1	Improving data security and privacy of students, staff and Lecturers	F	113	75	29	7	4
		%	49.6%	32.9%	12.7%	3.1%	1.8%
D2	Compliance with legal law and regulatory bodies	F	36	107	66	13	6
		%	15.8%	56.9%	28.9%	5.7%	2.6%
D3	Pace of keeping up with latest technology	F	76	89	47	8	7
		%	33.5%	39.2%	20.7%	3.5%	3.1%
D4	Reduced budgeting for cost of cyber breaches	F	62	89	44	24	7
		%	27.4%	39.4%	19.5%	10.6%	3.1%
D5	Maintaining public reputation in terms of gaining trust and confidence	F	73	82	43	13	17
		%	32%	36%	18.9%	5.7%	7.5%

The results indicate that majority of respondents (49.6%) strongly agree that cloud cybersecurity may improve data security and privacy of students, lectures, and staff. This can be achieved by increasing cybersecurity awareness campaigns and introducing mandatory short courses regarding various aspects of cybersecurity. Participants' may have strongly agreed as they may have found cloud cybersecurity as an advanced security option for improving privacy of their data. Some participants may have disagreed (4.9%) as they might be comfortable with the current security of their data or might have a belief that cloud cybersecurity does not have any significant difference in securing their data. About 56.9% of respondents agree that compliance with regulatory bodies could be a driver for adopting cloud cybersecurity in higher education institutions. The respondents might have agreed considering the significant role of laws and regulatory bodies within tertiary environment, whilst some might have disagreed (8.3%) with a belief that laws, and regulatory bodies may not be a strong influence towards adoption of technology. However, only 39.2% believes that, keeping up with latest technologies motivates higher education institutions in adopting cloud-based cybersecurity services. Respondents agreeing may have a belief that keeping up latest technologies might enable the tertiary environment to progress faster. Approximately 27.4% strongly agree and 39.4% agree that financial benefits and cost reduction are drivers of adoption. Respondents may have agreed with the belief that higher education institutions could be more financially feasible by using technologies with lower costs and cyber breaches could be addressed at a cheaper cost, while 13.7% have a belief that technologies at reduced costs may not be productive. Lastly, 36% of respondents agree that maintaining public reputation influences the adoption of cloud cybersecurity. Respondents may believe that using most recent technologies in securing the data would create a positive image and gain the stakeholders' trust.

Benefits of cloud-cybersecurity adoption

Table 8 illustrates the benefits of cloud-cybersecurity based on the respondent's knowledge, experience, and opinions.

Table 8: Cloud cybersecurity adoption benefits

Benefits of cloud cyber security adoption					
1. Educational/Administrative			**2. Technical (IT staff perspective)**		
	F	**%**		**F**	**%**
a. Prevents forgery	136	22.1%	a. Cheaper security costs as data is saved in multiple locations	8	22.9%
b. Prevents presenting false identity	136	22.1%	b. Standardized interfaces for managed cybersecurity services	7	20.0%
c. Prevents interference upon controlled conversations	114	18.5%	c. Provisioning of cybersecurity auditing	3	8.6%
d. Prevents altering date stamps on submitted work, files & documents	103	16.7%	d. Increased support for defensive measures when cyber-attacks are taking place	10	28.6%

Benefits of cloud cyber security adoption					
1. Educational/Administrative			2. Technical (IT staff perspective)		
	F	%		F	%
e. Prevents students/staff/ lecturers from gaining access to personal data of students/staff/lecturers	107	17.4%	e. Efficient and effective capabilities of incident/ attack response	7	20.0%
f. None	20	3.2%	f. None	0	0%

From the educational and administrative benefits, majority of responses indicate preventing forgery (22.1%) and presenting false identity (22.1%) as key benefits of cloud-based cybersecurity adoption. It can be assumed that most of the respondents believe that cloud cybersecurity can be a solution to eliminate or reduce fraudsters from having access to the systems at work or study areas. The results also indicate respondents' awareness of counterfeited documents circulated on online platforms for several illegal reasons which could be prevented through cloud cybersecurity. From the technical perspective, most respondents (28.6%) believe increased support for defensive measures as a benefit for adoption. This can be due to the fact the cloud-based activities are under continuous surveillance which could detect attacks early.

Quality perceptions of cloud-cybersecurity adoption

The quality of cloud cybersecurity could affect and contribute to the respondents' decision of adoption and usage. The quality measures were adopted from the ISS model (DeLone & McLean, 2016). The respondents were required to rate their level of agreement or disagreement to the corresponding perception on a scale of 1-5. Table 9 established the quality perceptions of stakeholders at the University of Venda. The results implied that although most of the respondents agreed with the numerous quality perceptions, accuracy and effectiveness of cloud cybersecurity occurred to be a dominating element receiving the maximum level of agreement (48.7%).

Table 9: Quality Perceptions of cloud cybersecurity adoption

	Quality Perceptions of Cloud-Cyber Security Adoption						
	Quality Factors		**SA**	**A**	**N**	**D**	**SD**
Q1	Reliability and flexibility of cloud-cybersecurity	F	91	102	29	3	3
		%	39.9%	44.7%	12.7%	1.3%	1.3%
Q2	Accuracy and effectiveness of cloud-cybersecurity	F	60	107	45	10	6
		%	26.3%	48.7%	19.7%	4.4%	2.6%
Q3	Consistency and relevancy of cloud-cybersecurity	F	57	103	48	14	5
		%	25.1%	45.4%	21.1%	6.2%%	2.2%
Q4	Responsiveness of cloud-cybersecurity	F	60	103	45	13	4
		%	26.7%	45.8%	20%	5.8%	1.8%
Q5	Increased value	F	53	102	57	12	4
		%	23.2%	44.7%	25%	5.3%	1.8%

	Quality Perceptions of Cloud-Cyber Security Adoption						
	Quality Factors		**SA**	**A**	**N**	**D**	**SD**
Q6	Quality of available infrastructure support of cloud-cybersecurity	F	57	82	51	22	16
		%	25%	36%	22.4%	9.6%	7%

Perceptions on awarenesss of cloud cybersecurity

The results of the respondent's perceptions and attitudes concerning cloud cybersecurity awareness are shown in Table 10.

Table 10: Awareness Perceptions of Cloud cybersecurity

	Perception on awareness of cloud cybersecurity						
	Awareness perceptions		**SA**	**A**	**N**	**D**	**SD**
A1	Cybersecurity maintains an up-to-date backup and recovery facility	F	74	88	49	14	3
		%	32.5%	38.6%	21.5%	6.1%	1.3%
A2	Prevention of unauthorized access to files when using cloud cybersecurity	F	63	95	44	14	11
		%	27.8%	41.9%	19.4%	6.2%	4.8%
A3	Security threats and consequences of cloud cybersecurity	F	61	88	54	14	9
		%	27%	38.9%	23.9%	6.2%%	4%
A4	Security training and awareness programs by various institutions	F	40	74	65	26	23
		%	17.5%	32.5%	28.5%	11.4%	10.1%
A5	The value of cybersecurity adoption	F	55	69	67	26	11
		%	24.1%	30.3%	29.4%	11.4%	4.8%
A6	Who to contact during a cybersecurity attack	F	38	56	64	29	20
		%	18.4%	27%	30.9%	14%	9.7%

The results indicate that a total of 71.1% were aware that cloud systems maintain an up-to-date backup and recovery facility. Respondents may have a belief that backup ought to be a fundamental facility of security systems. an aggregate of 69.7% were aware that cloud cybersecurity prevents unauthorized access to files and data. Respondents may have a belief that cloud cybersecurity could be an extra layer of security added to existing specialized security applications and software. 65.9% indicated to be aware of the security threats and consequents of using cloud services, while 50% were aware of the numerous security trainings and awareness programs. Various cybersecurity trainings and courses are being advertised on numerous social media platforms and internet.

Intention of Use

Figure 4 illustrates that 25% and 41% of respondents strongly agreed and agreed to adopt and use cloud-based cyber-security if service is provisioned y higher education institutions. However, a total of 16% of respondents had no interest in adoption, while 18% remained neutral regarding the adoption decision.

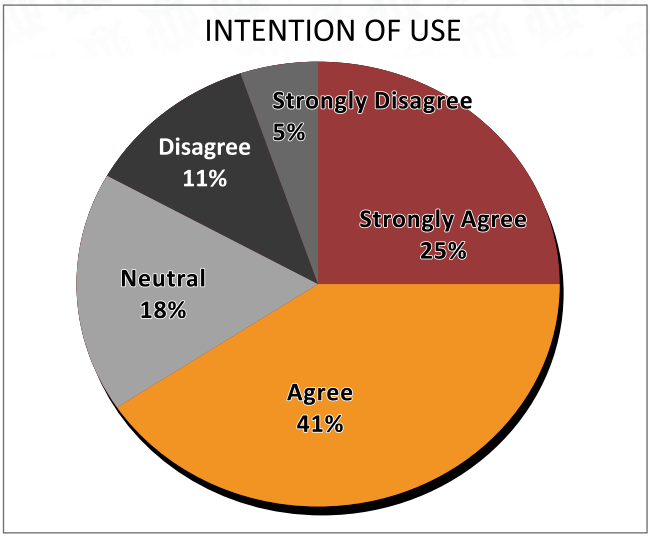

Figure 3: Intention of use of cloud-cybersecurity

The proposed framework

The cloud cybersecurity adoption framework as presented in Figure 4 is proposed based on the findings of the study. Some background information regarding cybersecurity policies, frameworks, audits, and strategies was obtained. The IT staff at University of Venda revealed that the institution does not have any cloud-based cybersecurity policies implemented for maintaining cyber-attacks and also does not have any cyber-security adoption framework established within their cloud platforms. Additionally, no regular third-party audits were conducted with cloud providers concerning cybersecurity as well as no strategies were distributed to employees to protect systems from cyberattacks. Thus, a suitable cybersecurity adoption framework is proposed to assist in successful adoption and usage of cloud-cybersecurity within higher education institutions in South Africa. The critical elements are briefed as follows:

- The framework includes specific cybersecurity drivers as reflected in Figure 4 that has an influence on adoption based on data obtained. These drivers promote the use of cloud-cybersecurity within higher education institutions. Thus, it is suggested that the South African government in alignment with tertiary institution authorities ought to develop suitable cybersecurity laws and regulations. The drivers could be a foundation for developing roadmaps for short- and long-term cloud-cybersecurity adoption goals.
- The benefits of cloud cybersecurity affect the adoption and thus play a pivotal role in facilitating its use; hence it was supported as a possible predictor. The benefits as visible in Figure 4 were realised because most of the respondents have used the cloud technology.
- The challenges may limit the higher education institutions in adopting cloud cybersecurity as participant's have shown to be aware of the drawbacks to some extent as presented in Figure 4. For this reason, higher education institutions may be limited by their capabilities in performing some tasks of running the cybersecurity systems within their IT environment.

Therefore, assurance is required from cloud providers in handling the identified challenges geared towards internal and external operational environment of higher education institutions by means of adequate plans, designs, implementations, and management of cybersecurity systems.

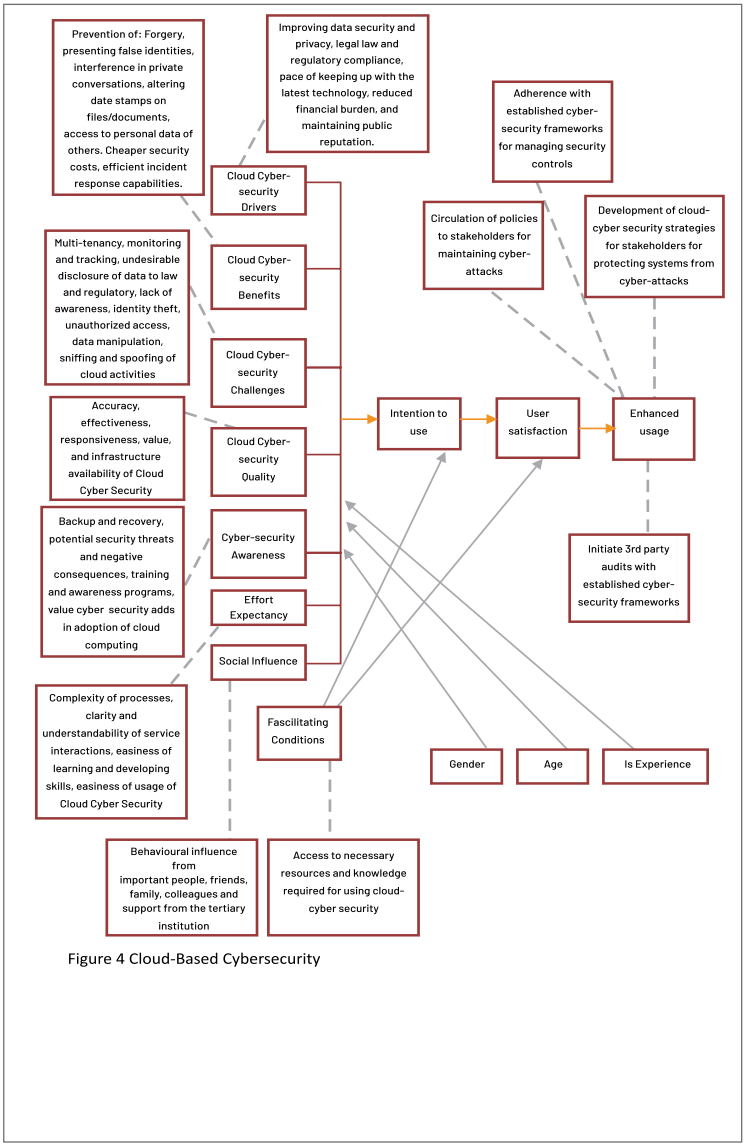

Figure 4 Cloud-Based Cybersecurity

Figure 4: Cloud-based cybersecurity adoption framework

- The quality attributes are significant towards adoption, since the higher the quality, the higher the value it adds towards the security which could improve the probability of pursuing positive intentions and higher user satisfaction within the higher education institutions (DeLone & McLean, 2016).
- Lack of awareness may delay the adoption (Apulu, 2012), whilst improved awareness may result in understanding the potential of cloud cybersecurity in the field of teaching and learning as well as research (Ayooluwa, 2016; Chibaro, 2015; Introna, 2015; Kajiyama, 2012; Siyaboni, 2012). Most participants have shown to be aware of the value of cloud-cybersecurity and its related aspects. For participants who were not aware, resources such as websites, guides and help desk support are required for recognising the capabilities and issues of cloud-cybersecurity.
- The effort expectancy perceptions were based on the fact that, most of the respondents were using cloud-based applications such as Gmail, Microsoft office, and Dropbox. For the cloud-cybersecurity to be diffused successfully, it must be convenient, efficient, less complex, and easy to use for staff, students, and academics. Simplicity of cloud-cybersecurity could be a significant influencing factor in adoption specifically for users with less computer skills. Most of the participants believed that cloud cybersecurity would be clear to understand, and skills could be easily developed.
- Social influence could be a non-existing factor for users with a disadvantaged background as it depends on the environment in which users are located. The findings revealed that social influence positively affects the adoption of cloud-based cybersecurity.
- Facilitating conditions was a significant factor in influencing the adoption because most respondents have agreed to have availability of resources, infrastructure, and IT support within the tertiary institution. Trainings and IT support should be organised for the respondents who have disagreed to have access to the resources. The assessment of the availability or absence of the facilities required in the adoption of cloud-based cybersecurity should be in alignment with the existing practice of cloud computing usage.

Conclusion

The research sought to determine the benefits, drivers, quality perceptions and awareness perceptions of cloud-based cybersecurity within higher education institutions using a case study of University of Venda. The study was based on and guided by the ISS and UTAUT theories. The effects of quality and awareness of cloud cybersecurity were taken into consideration as significant factors in the proposed framework. The findings revealed that the participants in the study intended to use cloud cybersecurity systems within the teaching and learning environment which could enhance their security experiences. The findings indicate that a cloud-based cybersecurity system ought to be implemented within higher education institutions. Various departments within the higher education institutions should analyse their specific cybersecurity requirements with an evaluation of costs/benefits and risks. Given the possible scale of societal transformation linked to the Fourth Industrial Revolution, cloud computing will increasingly become a critical platform for the delivery of computing resources which transcends limitations of size, space, and cost, among other advantages. However, it is critical to ensure that these computing resources are well-secured on a larger scale particularly since cloud computing is based on the open infrastructure of the Internet. The findings of this study have informed the proposed framework that can guide higher education institutions in South Africa in developing cyber security frameworks for the Fourth Industrial Revolution.

References

African Union. (2014). *African Union Convention on Cyber Security and Personal Data Protection*. Arican Union. http://pages.au.int/sites/default/files/en_AU Convention on CyberSecurity Pers Data Protec AUCyC adopted Malabo.pdf

Alharbi, N. (2016). *The role of security and its antecedents in e-government adoption* (Issue October). Plymouth University

Alshamaileh, Y. Y. (2013). *An Empirical Investigation of Factors Affecting Cloud Computing Adoption Among SMES in the North East of England* [Newcastle University Business School]. https://theses.ncl.ac.uk/dspace/bitstream/10443/2080/1/Alshamaila 13.pdf

Alshehri, M. A. (2012). *Using the UTAUT Model to Determine Factors Affecting Acceptance and Use of E-government Services in the Kingdom of Saudi Arabia* [Griffith University]. http://hdl.handle.net/10072/368130

Alvi, M. H. (2016). *A Manual For Selecting sampling Techniques in Research* (Issue march). https://mpra.ub.uni-muenchen.de/70218/1/MPRA_paper_70218.pdf

Annie, S., & Michael, H. (2013). NIST Cloud Computing Standards Roadmap. In *NIST Cloud Computing Standards*. https://doi.org/10.6028/NIST.SP.500-291r2

Apulu, I. (2012). *Developing a Framework for Successful Adoption and Effective Utilisation of ICT by SMEs in Developing Countries: a Case Study of Nigeria*. *February*, 3–369. http://wlv.openrepository.com/wlv/handle/2436/249899

Aretha, L. (2020). *UFH Law faculty collaborates with the National Consumer Commission to Introduce new Module | University of Fort Hare*. University of Forthare. https://www.ufh.ac.za/news/News/UFHLawfacultycollaboratesNationalConsumerCommissionintroducenewmodule

AWS. (2017). *Amazon Web Services – NIST Cybersecurity Framework* (Issue May). https://d0.awsstatic.com/whitepapers/compliance/NIST_Cybersecurity_Framework_CSF.pdf

Ayooluwa, P. K. (2016). Use of Web 2 . 0 Technologies for Teaching and Learning in Selected Federal Universities in Southwest Nigeria. In *University of KwaZulu-Natal*. University of KwaZulu Natal

Bacon-Shone, J. (2015). Introduction to Quantitative Research Methods. In *Graduate School, The University of Hong Kong* (Issue February). https://doi.org/10.13140/2.1.4466.3040

Bromiley, M. (2017). Zero-Touch Detection and Investigation of Cloud Zero-Touch Detection and Investigation of Cloud Breaches : A Review of Lacework ' s Cloud Workload Security Platform. In *Sans Institute InfoSec Reading Room*

Centre for Research in Information and Cyber Security. (n.d.). *Centre for Research in Information and Cyber Security*. Nelson Mandela University. Retrieved July 27, 2021, from https://crics.mandela.ac.za/

Chibaro, N. (2015). *Adoption of Cloud Pedagogy by Higher Learning Institutions in Southern Africa* (Issue November). Cape Peninsula University of Technology

Cieplak, T., & Malec, M. (2014). Applications of Cloud Computing Services in Education – Case

Study. *Advances in Science and Technology Research Journal*, *8*(24), 55–60. https://doi.org/10.12913/22998624/568

Costello, G., Donnellan, B., & Curley, M. (2013). A Theoretical Framework to Develop a Research Agenda for Information Systems Innovation. *Communications of the Association of Information Systems*, *33*(33), 443–462. http://aisel.aisnet.org/cais

CSIR. (2012). *Cyber Security Awareness*. http://defsec.csir.co.za/wp-content/uploads/2012/09/Cyber-Awareness-Fact-Sheet-2.pdf

DeLone, W. H., & McLean, E. R. (2016). Information Systems Success Measurement. *Foundation and Trends in Information Systems*, *2*(1), 1–32. https://doi.org/http://dx.doi.org/10.1561/2900000005 Information

Dlamini, Z., & Modise, M. (2012). Cyber Security Awareness Initiatives in South Africa: A Synergy Approach. *7th International Conference on Information Warfare and Security*, 10. https://doi.org/10.1007/978-3-8349-4134-3_3

E&Y Inc. (2015). Cybersecurity and the Internet of Things. In *E&Y* (Issue March). http://www.ey.com/Publication/vwLUAssets/EY-cybersecurity-and-the-internet-of-things/$FILE/EY-cybersecurity-and-the-internet-of-things.pdf

Enisa. (2012). National Cyber Security Strategies. *ENISA*, *May*, 15. https://doi.org/10.2824/3903

Enterprises University of Pretoria. (n.d.). *cybersecurity I- shifting knowledge to insight.* University of Pretoria. Retrieved July 26, 2021, from http://www.enterprises.up.ac.za/info-brochure/Cyber Security 1.pdf

Fink, A. (2016). How to Conduct Surveys. In C. K. Tricia (Ed.), *In How to Conduct Surveys. A Step by Step Guide* (6th ed., pp. 67–91). SAGE Publications Ltd. https://jerosystems.com/2016/rskills4.pdf

Fowler, F. J. J. (2009). *Survey Research Methods* (5th ed., Vol. 4th). SAGE Publications Ltd. https://books.google.co.za/books?hl=en&lr=&id=CR-MAQAAQBAJ&oi=fnd&pg=PP1&dq=survey+research+design+pdf&ots=KOrIIXRTKU&sig=EBlLN6Mofwdy6d1xPpEW4YbqUmg#v=onepage&q&f=false

Fumeaux, G. (2016). *Thesis Project Public Software as a Servic- A Business Driven Risk Control*. Linnaeus University

George, A. . (2015). Conceptual Framework For The Study of Factors Affecting Teachers' Use of Technology [University of the Witwatersrand]. In *Applied Cognitive Psychology*. http://wiredspace.wits.ac.za/jspui/bitstream/10539/16919/4/04.pdf

Grobler, Flowerday, S., Von Solms, R., & Venter, H. (2011). Cyber Awareness Initiatives in South Africa: A National Perspective. *Proceedings of Southern African Cyber Security Awareness Workshop (SACSAW)*, *32*, 32–41. https://researchspace.csir.co.za/dspace/bitstream/handle/10204/5164/Grobler2_2011.pdf?sequence=1&isAllowed=y

Haeberlen, T., & Lionel Dupré. (2012). *Cloud Computing - Benefits, Risks and Recommendations for Information Security*. http://www.enisa.europa.eu

Hall, J. (2011). Encyclopedia of Survey Research Methods Cross-Sectional Survey Design. In *Encyclopedia of Survey Research Methods* (pp. 173–174). SAGE Publications Ltd. http://methods.sagepub.com/base/download/ReferenceEntry/encyclopedia-of-survey-research-methods/n120.xml

Introna, N. (2015). *A Cloud Computing Adoption Framework for Financial Service Institutions in South Africa* [University of Fort Hare]. http://libdspace.ufh.ac.za/bitstream/handle/20.500.11837/801/NicoletteIntrona_Masters_Complete_v5_Corrections_FINAL_LeatherBindingpdf?sequence=1&isAllowed=y

Jaquire, V. J. (2015). *A Best Practice Strategy Framework for Developing Countries to Secure Cyberspace*. University of Johannesburg

Kajiyama, T. (2012). *Cloud Computing Security: How Risks and Threats are Affecting Cloud Adoption Decisions* [San Diego State University]. http://sdsu-dspace.calstate.edu/handle/10211.10/3522

Khoza, S. (2021). *Remote Workers (Cybersecurity Awareness Campaign) | University of Venda*. UNIVEN. https://www.univen.ac.za/news/remote-workers-cybersecurity-awareness-campaign/

Kumar, G., & Chelikani, A. (2011). Analysis of Security Issues in Cloud Based E-Learning. *Security Management*, 1–74

Lee, K. R., & Chavannes, R. de. (2013). *Impacts of Information Technology on Society in the New Century*. StudyMode Research. https://www.zurich.ibm.com/pdf/news/Konsbruck.pdf

Liya, X. (2014). Readiness Assessment of Cloud-Computing Adoption within a Provincial Government of South Africa. In *4th International Conference on Design, Development & Research* (Issue September 2014). University of Western Cape

Loanzon, E. (2014a). A Proposed Road Map for Cybersecurity in Cloud Computing at Portland State University. In *Planning and Roadmapping Technological Innovations: Cases and Tools* (pp. 177–213). Springer, Cham. https://doi.org/10.1007/978-3-319-02973-3

Loanzon, E. (2014b). *Planning and Roadmapping Technological Innovations* (R. T. Tugrul U. Daim, Melinda Pizarro (ed.)). Springer Science+Business Media. https://doi.org/10.1007/978-3-319-02973-3

Maynard, A. D. (2015). Navigating the fourth industrial revolution. *Nature Nanotechnology*, *10*(12), 1005–1006

Mkhize, A. (2021). *Unisa initiative to equip school-children and parents about cyberspace*. Social TV - Corporate, Social. Investment. News. https://social-tv.co.za/unisa-initiative-to-equips-school-children-and-parents-about-cyberspace/

Mmthembu, Z. (n.d.). *Information and cyber security roadmap | Article | University of Pretoria*. University of Pretoria. Retrieved July 26, 2021, from https://www.up.ac.za/itsecurity/article/2877690/information-and-cyber-security-roadmap

Muheidat, F., & others. (2021). Mobile and Cloud Computing Security. In *Machine Intelligence and Big Data Analytics for Cybersecurity Applications* (pp. 461–483). Springer

Neuman, W. L. (2009). *Social Research Methods: Qualitative and Quantitative Approaches* (7nth ed.).

Pearson. https://www.pearson.com/us/higher-education/program/Neuman-Social-Research-Methods-Qualitative-and-Quantitative-Approaches-7th-Edition/PGM74573.html

NIST. (2016). *Federal Information Security Management Act*. https://www.nist.gov/programs-projects/federal-information-security-management-act-fisma-implementation-project

Nyoni, T. B. (2014). *Towards a Framework for Enhancing User Trust in Cloud Computing*

Panda, D. R., Behera, S. K., & Jena, D. (2021). A Survey on Cloud Computing Security Issues, Attacks and Countermeasures. In *Advances in Machine Learning and Computational Intelligence* (pp. 513–524). Springer

Patala, N. N. (2017). *The Impact of Cloud Computing Usage on Educational Institutions: a Case Study on University of Venda*. Unpublished thesis for Master of Commerce degree in the School of Management Sciences, University of Venda

Phillips, B. (2007). A Theoretical Framework for Information Systems Portfolio Management A Theoretical Framework for Information Systems Portfolio Management. *Americas Conference on Information Systems (AMCIS)*, 1–7. http://aisel.aisnet.org/amcis2007

Qasem, Y. A. M., Abdullah, R., Jusoh, Y. Y., Atan, R., & Asadi, S. (2019). Cloud Computing Adoption in Higher Education Institutions: A Systematic Review. *IEEE Access*, *7*, 63722–63744. https://doi.org/10.1109/ACCESS.2019.2916234

Siyaboni, J. L. (2012). *Factors Influencing Cloud Computing Readiness In Small and Medium Enterprises*. Tshwane University of Technology

Sterbenz, R. (2017). *The Evolution of Cybersecurity in the Cloud*. Cisco. https://observable.net/blog/the-evolution-of-cybersecurity-in-the-cloud-infographic/

Tout, S., Sverdlik, W., & Lawver, G. (2009). Cloud Computing and its Security in Higher Education. *The Proceedings of the Information Systems Education Conference*, *26*(11), 1–5. https://doi.org/10.5176/978-981-08-5837-7_201

Tripathi, A., & Mishra, A. (2011). Cloud Computing Security Considerations. *2011 IEEE International Conference on Signal Processing, Communications and Computing (ICSPCC)*, 1–5. https://doi.org/10.1109/ICSPCC.2011.6061557

UNISA. (2017). *Cyber Security Awareness Community Engagement Project*. UNISA. https://www.unisa.ac.za/sites/corporate/default/Colleges/Science,-Engineering-&-Technology/Community-engagement/Community-engagement-Projects/CSACEP

Uudhila, J. M. (2016). *Cyber Security Risk Management and Threat Control Model* (Issue March) [The University of Namibia]. https://repository.unam.edu.na/bitstream/handle/11070/1688/Uudhila_2016.pdf?sequence=1

Vidyasagar, S., & Murugan, A. (2021). A Study on Security Services and Threats in Cloud Computing. *Annals of the Romanian Society for Cell Biology*, 180–192

Waughray, D., Herweijer, C., & Leape, J. W. (2018). Harnessing the fourth industrial revolution for the earth. *World Econ. Forum*.

No. 1 Quintin Brand Street
Persequor Technopark
Brummeria
Pretoria
South Africa

+27 12 349 3840
www.che.ac.za

ISBN: 978-1-928533-79-5